

811
819
28
37
48
50
54
81
37
39
75
80
3
6

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GLIMPSES OF FOREIGN WATER WORKS¹

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Water works structures constitute some of the major public works under construction in foreign municipalities. In the past decade there has been an increase of interest in good water supplies, good in both quality and quantity. A result has been the expenditure of large sums of money and the creation of fine structures and exemplary works for obtaining, purifying, and distributing water. The impetus of this interest is not yet exhausted as works of magnitude are contemplated for the immediate and the remote future. A glance at water works practice the world over will show much to the American water works engineer.

Generalizations on world-wide practice might be misleading by giving the impression that there is similarity in water works design and operation. It is true that the problems presented in Manchuria may be similar in many respects to those met in Montana, or Kingston, Jamaica may find difficulties similar to those of Honolulu, but it is probable there will be sufficient difference in the solution of the problem and in the minds of the solvers to present very different results in the water works structures erected. There are a few general tendencies and practices which are marked and which are gratifying to American water works men. First, there is a tendency towards

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the adoption of the rapid sand filter either to replace or to supplement the slow sand filter. The latter persists through inertia and ignorance; inertia due to its successful use for generations and through ignorance because of the greater amount of experience and training required for the operation of a rapid sand filter; second, the general adoption of the use of chlorine in the disinfection of public water supplies; and third, the wide use of the Standards of Quality of Potable Water adopted by the United States Public Health Service.

WATER WORKS ACTIVITIES

Water works seem as essential to municipal life as air or food to individual existence and public water works are to be found in most cities, except in China. Life in China is a contradiction to the best and most cherished maxims of Occidental standards of living. There are some cities in China which have no public water supplies, but, on the other hand, there are fine water works in Canton, Shanghai, and in portions of Peking and Tien Tsin. Quality standards of the United States Public Health Service are becoming the standards of quality for public water supplies in those parts of the world where water quality is considered, and there are few places today where the quality of water is not a paramount consideration. Water purification plants and extensions to water works systems are under construction or are contemplated in many cities. Some of the more important of these works which are contemplated in cities on the other side of the world are as follows:

Yokohama: Extension to rapid sand filter plant now under way.

Osaka: New rapid sand filter plant just completed.

Kobe: New rapid sand filter plant just completed.

Tien Tsin: British Municipal Council, new rapid sand filter plant just completed.

Shanghai: New rapid sand filter plant under construction.

Hong Kong: New rapid sand filter plant under construction, extensions to distribution system, and to submerged pipe line under harbor, under construction.

Manila: New rapid sand filter plant and other extensions to works under construction.

Batavia (Java): Extension to rapid sand filter plant is contemplated.

Calcutta: A comprehensive renovation of the aqueduct and extension of the slow sand filter plant has recently been completed.

Singapore: New rapid sand filter plant and masonry dam just completed and other dams are under construction.

Bangkok: Rapid sand filter plant is being doubled in capacity.

Cairo: Rapid sand filter plant is being increased in capacity.

Honolulu: The construction of a rapid sand filter plant and an impounding reservoir are contemplated.

ARTESIAN WELLS TO FAIL WHILE FLOWING

The condition of Honolulu's water supply is such that the usefulness of the artesian wells, upon which the city depends for its water supply, will be exhausted when the elevation of the artesian ground water table reaches 5 to 10 feet above the ground surface. This surprising situation is due to the peculiar underground conditions so close to the Pacific ocean. The water reaching Honolulu's wells is precipitated upon the slopes of nearby mountains and, percolating through a porous stratum overlain by impervious strata, it reaches Honolulu's wells about 600 feet below the general level of the ground on which the city is built. The water-bearing stratum outcrops on the bed of the ocean in such a manner that the weight of the column of fresh water must exceed the weight of a column of salt water in order to maintain a flow of fresh water to the ocean. Unless the fresh water flows continuously to the sea with an adequate velocity an inflow or even a diffusion of salt water will enter the wells.

Since the depth of the wells is approximately 600 feet it has been estimated that salt water will contaminate the wells when the artesian water level sinks below elevation 22 (feet) above sea level. From an original elevation of 42 the water level had sunk to elevation 28 in 1929, resulting in the making of active efforts to find a supplementary source of supply. It is, therefore, probable that an impounding reservoir and a rapid sand filter plant will be constructed in the near future to supplement the well water supply.

JAPANESE WATER WORKS ARE OCCIDENTAL

Water works in the larger cities of Japan are as modern and as advanced as those in any of the larger cities of the Occident. The Japanese people are attaining Western standards of living and are demanding those facilities of municipal life which are considered essential in the Western Hemisphere. Most public water supplies in Japan have been installed in the past twenty years. These works have been designed by Japanese engineers who have studied in Europe or in the United States and the works erected reflect the effect of these studies. It is gratifying to Western pride to observe the Occidental influences existing in Japanese water works practice. To

the eye of an American observer American influences predominate. Probably to the eye of a British observer British influences predominate.

Evidences of foreign influence on Japanese water works practice is no reflection on Japanese national pride. It is natural that foreign methods should influence the Japanese and they have shown their good sense and sound judgment by observing the better things in foreign practice and by imitating them. The foreigner, in visiting Japan, can see what is considered best in his own practice by seeing those things which the Japanese have copied because that which the Japanese has copied he considers good.

ORIGINALITY AT OSAKA

Imitation cannot be carried to the minutest detail and imitation cannot offer a solution for all of the problems of any particular city. In the design of the water works of Osaka there is no other city on earth in which the conditions are exactly the same. Osaka, Japan's largest city with a population of 2,408,000, draws its water from the river at Kunishima about 20 miles below the sewer outfall of the city of Kyoto which has a population of 755,000. Between Kyoto and Osaka there are a few small villages which discharge sewage into the river but the pollution at the Osaka water works intake is not extreme because of the high dilution and the self-purification of the river. In order to relieve the load on the filter plant and to maintain the highest standard of sanitation it is planned to move the intake of the Osaka water works above the outfall of the Kyoto sewers, thus securing a water of unquestionable quality, but involving the construction of a 25-mile aqueduct to attain the desired end.

The water supply of Osaka is first settled in sedimentation basins, of which there are ten operated on the continuous flow principle, giving periods of retention between 2 and 6 hours, dependent upon the quality of the raw water. Sedimentation is aided at times by the application of a small amount of alum. After preliminary treatment in the sedimentation basins the water flows to the slow sand filters, of which there are 24 units, each approximately one acre in area and operated at a rate of 4 million gallons per acre per day, or, as the Japanese express it, 12 feet per day. The plant has a nominal capacity of 75 million gallons per day and is provided with six clear water basins each with a capacity of 5,500,000 gallons, giving a possible storage period of 10 hours, based on the nominal capacity of the plant.

The capacity of the slow sand filter plant was found to be inadequate in 1929 so that a supplementary rapid sand filter unit has recently been completed. It has a nominal capacity of 30 million gallons per day and was completed in 1930. It was constructed by the Pittsburgh Filter Company in accordance with American practice so that it presents no novel feature to an American water works engineer other than its presence in the Orient. The distribution system covers the greater portion of the city and water is available in most houses as is indicated by the absence of hydrants from which the public may draw water.

ANCIENT AND MODERN WORKS IN TOKYO

Tokyo, the capital and the second largest city of the Empire, has a population of 2,294,000. Its first water works were constructed about 1590 with periodic changes and additions since then. The present works were started about 1892 and are entirely independent of the ancient system. At present water is taken from the Tama river and flows to two storage reservoirs with beautiful surroundings at Murayama. These two reservoirs have a total capacity of 3,300 million gallons. The water runs by gravity from the reservoirs to the slow sand filter plant in Tokyo where it is filtered at the standard rate of 12 feet per day, and is then pumped into the distribution system. The average daily rate of consumption during 1927, the latest available statistics, was 94 million gallons, or about 47 gallons per capita per day, based on a tributary population of 2,000,000. This quantity was supplied to 263,205 hydrants and 350,200 houses. Water is now available throughout the city for all purposes including fire fighting.

POWER AND POTABILITY COMBINED IN KYOTO

The water supply of Kyoto is taken from Lake Biwa, a mountain lake of great size, the largest in the Empire. The water is used for power, canal feeding, and other purposes in addition to its use as a public water supply. It is led to the city through twin conduits with a combined capacity of 850 second feet. Of this amount 150 second feet, or 50 million gallons per day is used for the public water supply. There are two water purification plants in Kyoto. The older plant, located at Keage, supplies water to 450,000 people. It is equipped with 20 tub filters of the Jewell type washed with air and water and cleaned by mechanical rakes. The newer slow sand filter

plant, located at Matsugasaki, will care for 250,000 people. About 90 per cent of the population uses the public water supply and consumes an average of 20 million gallons daily.

NEW PLANTS AT KOBE AND YOKOHAMA

The combined slow and rapid sand filter plant at Kobe is one of the finest in Japan. The city is an important seaport and has a population of 673,000. The purification plant includes six slow sand filter units built many years ago and a new rapid sand filter plant completed in 1929. The combined capacity of the two filter plants is 25 million gallons daily. Yokohama, the most important port of the Empire, also completed a rapid sand filter plant in 1929 to supplement its older slow sand filters. The water supplies of both cities are taken from surface sources in the nearby highlands and are led to the cities by gravity, the treatment plants being located at convenient points so that advantage can be taken of gravity in the distribution of water, with very little pumping being required. The modern water works of Yokohama were started in 1871 as a private enterprise. They were soon purchased by the local government, however, and have been greatly developed since then. The water for Yokohama is now taken from the Sagami River at Aoyama, about 26 miles from the city at an elevation of 500 feet above sea level and is led into storage and settling basins near the intake. After sedimentation the water passes through two aqueducts to the filter plants: one at Kawai about three miles from the city limits and the other at Nishiya just within the city. The filtered water reservoir at Nogeyama is on a hill in the heart of the city and water flows from the reservoir into the distribution system by gravity.

At Kawai the filter plant is of the slow sand type with a capacity of 500,000 gallons per day. The plant at Nishiya includes eight slow sand filter units with a capacity of 20 million gallons per day, and a rapid sand filter plant of the Jewell type with rectangular box filters, completed in 1929, with a capacity of 10 million gallons per day. This plant is equipped with modern appurtenances including dry-chemical feed devices, automatic rate controllers, is cleaned by water alone, and has adequate coagulation and mixing capacity.

KOREAN WATER WORKS COSTUMES

To put on a night dress and a funny hat in order to dig a ditch would be an initiation stunt worthy of the roughest of secret societies,

yet the latest improvements to the water works at Keijo, the capital of Chosen (possibly better known as Seoul, the capital of Korea), are being made by men so clothed. The funny hat has the appearance of a much-too-small Puritan stove pipe set high on the top of the head and held there by wide black strings tied under the chin. It's an old Korean custom.

The water for the city, which has a population of about 350,000, is taken from the Han river about 5 miles above the city, where the purification plant is located. The first slow sand filters were constructed at this site in 1904 with a capacity of 4 million gallons per day. As this became quite inadequate to supply the demand a new source of supply is being developed. This consists of thirty-four 8-inch wells sunk to a depth of 50 feet close to the river and near to the present river intake. The additional construction includes a pumping station, but no extension to the filter plant. In the meantime a supplementary supply is being borrowed from the suburb of Jinsen which also draws its water from the Han River and filters it through slow sand filters.

SOME JAPANESE WATER WORKS IN MANCHURIA

Port Arthur and Dairen are names which recall the stirring events of the Japanese-Russian War. They are two beautiful cities located within a dozen miles of each other at the southernmost point of Manchuria. Dairen is a wealthy sea port serving as an outlet for the products of Manchuria, one of the most productive and richest of Chinese provinces and one which is only partially developed. Port Arthur is in a back wash of progress having lost its importance when the Japanese developed Dairen. A joint water supply serves the two cities whose combined population is 200,000. Water is secured by impounding a small stream with a watershed of 32 square miles on which the annual rainfall is about 16 inches. The Ryoto dam which forms the reservoir is of masonry, 131 feet high and 518 feet long, and impounds 4,200 million gallons. The supply is scarcely adequate for the demand because of the long dry periods so that further developments are contemplated for the near future. The slow sand filter plant at Dairen has a capacity of 5 million gallons per day which is about sufficient to supply the daily per capita demand of 33 gallons.

CHINESE CONTRASTS

If Japan presents the impression of modernity and progress in water works then China presents almost the reverse impression.

Political, financial, social, and living conditions are such among the Chinese that there is no incentive to the development of a public water supply and cities with immense populations exist without public water works. Canton, the historically progressive Chinese city is one of few if not the only city in China which possesses a modern water works owned and developed entirely by Chinese. All other water works have been the result of foreign enterprise, were constructed mainly to serve foreign districts, and have later been extended to serve the Chinese. In Pekin and Tsing Tao the water works are now operated by Chinese but they were constructed by Germans and were operated by them until the World War. The works at Pekin were obtained by purchase from the original owners, those at Tsing Tao passed into Chinese hands through the Japanese who captured the city from the Germans. There is a Chinese Native City Water Works in Tsin Tsin, but a large share of it is owned by foreigners and the operating officials are Scandinavians. The British Municipal Council operates a water works to supply the British concession and the former Russian concession which is now controlled by the Chinese.

That part of Shanghai which is occupied by the Chinese is supplied from native water works and there are minor works of ancient type in other cities, but, in general, the Chinese depend upon the private well, the canal, and the water vendor who obtains his water from questionable sources. The ancient practice recommended even before biblical times, of placing a small amount of alum in the water and allowing it to settle is practiced by these vendors in order to improve the appearance and salability of the water. Widely prevalent insanitary conditions, fertilizing the soil with human manure, and other practices abhorrent to Occidental standards would seem to preclude the necessity for a laboratory analysis to demonstrate the existence of disease germs in surface sources of water in China. The teeming populations and the evident comparative freedom from water-borne diseases both in China and in British India introduce a possible question into our honored sanitary creed that to drink polluted water will produce disease. I have seen thousands consume water in which evidences of recent pollution were disgustingly apparent to the eye and to the nose, yet probably none of those thousands contracted disease. Why? Whose guess is the best? Is it a bacteriophage? Is it racial immunity? It is easier to ask questions than to answer them, yet millions of insanitary acts are com-

mitted in the Orient without the expected result until something goes wrong with the balance and a death-dealing scourge sweeps through the people to reduce the population.

RAPID SAND FILTRATION IN FAVOR AT SHANGHAI

It is probable that the first water filters to be constructed in the Far East were those at Shanghai which were built in 1881. The rise of popularity of the rapid sand filter is indicated by the progressive replacement of the slow sand filter units at Shanghai by the construction of rapid sand filters on their site. This is due not to dissatisfaction with the slow sand filters, but to the necessity of increasing the capacity of the works for the International City without increasing the area occupied by the purification plant. In 1929 the purification works consisted of 12.8 acres of slow sand filter units and a rapid sand filter of the Paterson type with eight filters and a nominal capacity of 28.8 million gallons per day. A duplicate of this rapid sand filter plant was under construction in 1929 and 1930.

INTERNATIONAL DIPLOMACY AND WATER WORKS

In 1927 or 1928 there was a water famine in Hong Kong which was so severe as to threaten the existence of the city. It became necessary to import water by ship from Shanghai, an expensive undertaking, and negotiations were opened for importing water from Manila. This dangerous condition has driven the British engineers on to the mainland for the collection of water at both Hong Kong and Singapore. The reservoirs and purification plants are both being constructed on foreign territory. The works for both of these cities were under construction in 1930.

Hong Kong is a British crown colony; it is neither a Chinese city, nor is it in China. The water supply problems of Hong Kong and Singapore are somewhat similar in that both are large cities located on small islands close to the mainland which is controlled by a foreign nation. The watersheds of the islands on which the cities are located are insufficient in area to provide all of the surface water required and there is no adequate ground water supply available. It is, therefore, necessary to go to the mainland to construct impounding reservoirs in foreign territory.

On the island of Hong Kong there are six impounding reservoirs and one river intake, giving a total available storage of 2,500 million gallons which will care for a demand of 8.7 million gallons per day,

slightly more than half of which must be pumped, the remainder flowing to the city by gravity. There are now three impounding reservoirs and one river intake on the mainland with a storage capacity of 600 million gallons capable of providing 6 million gallons daily. As the combined capacities of the island and mainland supplies is insufficient for the requirements of the two cities of Victoria and Kowloon which comprise the colony of Hong Kong additional reservoirs are being constructed on the mainland, a 12-inch cast-iron pipe line was laid, in December 1929, from the mainland to the island to connect the distribution systems of the two cities, and a rapid sand filter of the Paterson type was completed on the mainland in 1930 to supplement the existing slow sand and rapid sand filters. The entire water works will have a capacity of 20 million gallons per day when the new construction is completed in 1932. All water supplied to consumers will be filtered.

SINGAPORE'S SUPPLY

There are three impounding reservoirs located on the island of Singapore and two are on the mainland in the nearby Sultanate of Johore. The Sultan Ibrahim and the Pontian Kechil reservoirs on the mainland will have a combined capacity of 5,275 million gallons when they are completed. The Sultan Ibrahim reservoir was completed in 1929, and work is probably nearing completion on the Pontian Kechil project. When all of the reservoirs contemplated are completed the total available storage will be 8,034 million gallons.

In 1929 the rapid sand filter plant at Pula was completed with a capacity of 12.5 million gallons per day to purify the water from the two reservoirs on the mainland. It is unique as a rapid sand filter plant because of the absence of either coagulating basin or mixing chamber, the coagulants being added to the raw water as it flows on to the filters. Troubles developed from mud balls shortly after the plant was put into operation. As in most British cities the rapid sand filters have been installed recently only to supplement older slow sand filters. The Woodleigh plant, which was completed in 1910, includes 7 acres of slow sand filter beds and is located on the island of Singapore. The consumption of potable water is reduced by the use of 500,000 gallons daily of sea water which is used for street flushing and other cleansing purposes.

MANILA'S COMPREHENSIVE WATER WORKS

It's an old Spanish custom in Manila to take the public water supply from impounding reservoirs as no adequate ground water source has been developed. The oldest reservoir which is still in use is formed by the dam at Santolan which was constructed in 1882. This is a masonry structure about 50 feet high constructed in the narrow gorge of the Santolan river. The dam was designed to permit only a moderate depth of water to flow over it, but in 1929 a rain storm of cloudburst proportions put a discharge over the dam which topped the waste weir by 15 to 25 feet, the exact height being uncertain as all of the top works were swept away or damaged. The dam was uninjured because of an unforeseen factor of safety. The carrying capacity of the channel below the dam was too small to care for the excessive flood so that water was backed up over the top of the dam which became a submerged weir and was relieved from dangerous stresses.

The water supply of Manila is now taken from impounding reservoirs at Montalban, completed in 1910, and at Novaliches, completed in 1929. It flows by gravity to the distributing reservoir at San Juan just above the city. From here it is distributed by gravity and by pumps to the city. The Santolan supply is now reserved for emergency. The construction of a diversion dam across the Angat river was commenced in 1930. When the Angat Dam is completed it will be possible to supply 80 million gallons per day to the Metropolitan Water District which comprises about 350,000 persons. A rapid sand filter plant was to be completed in 1930 with a nominal capacity of 40 million gallons daily. This will fill the normal demand of the city and it is expected to furnish nothing but filtered water upon the completion of the filter plant. A unique feature of this plant is the general plan which attempts to fit the rough topography of the site which necessitates the construction of long, narrow coagulating basins curved to follow the contours of the hill side upon which they are constructed. The use of this peculiar site makes it possible to operate the plant without additional pumping.

The public water supply is supplemented by public and private wells, mostly of the artesian type, located within the city and delivering a water of safe sanitary quality, but of insufficient quantity. The public water supply is 100 percent metered, but one-third of it is unaccounted for.

AUSTRALIAN PROBLEMS

It would probably be generally conceded that the principal water works structures under construction in Australasia are those in connection with the public water supplies of Sydney and Melbourne and possibly including the Hume Dam of the Murray River Project. Doubt concerning the propriety of including the Hume Dam among large water works structures is due to its primary purpose for navigation interests, but one of its secondary purposes is to supply water for cities along the Murray River and its construction has created an interesting and difficult problem for water works engineers.

Sydney and Melbourne, the two largest cities in Australia, each have a population slightly greater than one million. Each obtains its water from surface sources in nearby hills through the construction of impounding reservoirs. The water is conducted by gravity to the cities and is there distributed by gravity with a small amount of supplemental pumping. The particularly interesting features of the water works are the character of the watersheds, the design and construction of the dams, the open canals for conveying the water, the screens at the upper end of the Sydney aqueduct, the long steel aqueducts for the Sydney supply, the open aqueducts for the Melbourne supply, and the labor conditions at the construction camps.

Vast areas of unoccupied lands are to be found within short distances of both Sydney and Melbourne. It is a condition not frequently found near such large cities in the northern hemisphere. One of the reasons given for the scarcity of population so close to the cities is the lack of fertility of the soil which will support nothing of great value. The topography is rolling; the country is covered with eucalyptus trees, and its valleys are deep with wide bottoms and steep sides. The condition is ideal for the construction of impounding reservoirs, for the protection of the watersheds, and for the collection of water of excellent quality. Almost 100 percent of the water sheds are controlled by the Metropolitan Water Works of each city and no unauthorized person is allowed upon the collecting areas.

HOLLOW CORE WALLS FOR EARTH DAMS

Earth dams with hollow core walls are of striking interest, the latest and most advanced design being that for the Sylvan Dam of the Melbourne Works. Knowledge of the advantages of the hollow type of core wall in dam construction is spreading slowly among engineers.

A patent on this type of construction was taken out in 1909 by N. L. Hall (see *Engineering News-Record*, April 9, 1931, p. 622), but relatively few of its type have been constructed. The Sylvan Dam is the first of its type to be constructed in Australia. It has been constructed to overcome the difficulties met with the Eildon Dam which failed due to the character of its core wall support, and to overcome difficulties which are anticipated with the early section of the Hume Dam because of its construction which is somewhat similar to that of the Eildon Dam.

A hollow core wall is constructed with vertical drainage channels in the downstream face of the wall, the channels being so designed that seepage water through the core wall can be seen by inspection and will be led away below the dam through a drainage tunnel in and under the dam in such a manner that the downstream portion of the earth embankment will remain dry and is thus protected from slips and other damages due to uplift and water content.

ALGAL TROUBLES ON AN IMMENSE SCALE

Algal pollution of a record-breaking extent was experienced in the new Hume reservoir which is formed by impounding the Murray River, the largest river on the continent, by the construction of the Hume Dam near Albury. The lake created is about 50 miles long and varies in width from 1 to 15 miles. Since public water supplies were not among the primary purposes of the creation of the lake no attempt was made to strip the watershed. About a year after the water had been allowed to rise to a depth of about 25 feet behind the dam, submerging the nearby forests, algal growths appeared. The water assumed a brilliant green color and gave off an offensive odor of freshly-cut weeds. In the shade the green color gave place to a dark purplish red which was particularly intense in the shadow of our motor boat in contrast to the surrounding green of the reservoir. Five hundred square miles of this polluted water constitutes an extensive algal growth and the intensity of the growth seemed approximately equal wherever the inspecting craft investigated into the reaches and backwaters of the reservoir. To treat all of this area and volume of water with copper sulphate, particularly in view of the almost unlimited food supply of decaying submerged vegetation seemed almost a hopeless task, yet the Australian water works engineers were so attempting to control the growth.

LIVING THE LIFE OF REILLY

Labor conditions in Australia are unique, particularly on construction jobs. In the construction of the Nepean Dam for the Sydney water supply the quarters for the workmen in the construction camp are of a semi-permanent style, erected on shaded and well-metalled streets, are provided with electric lights and running water, and most of the household conveniences which we call modern. Hospitals, stores, entertainment centers, and all of the desirable features of modern life are provided to keep the worker happy, together with a minimum wage and a classification of workers which is too complicated even for the men to understand in many cases.

MALAYAN MECHANICS

If labor conditions in Australia are interesting because of the supremacy of labor in government then labor conditions in Java are surprising for almost the opposite reasons, for here the Dutch Government is in supreme control. Yet the native Javanese makes a most satisfactory laborer and what is more surprising, he makes an excellent mechanic. To walk through the shops of the water works of Soerabaja and to see at lathes and drill presses, dark-skinned Malays of a type more often associated with pirate ships, is surprising. To express this astonishment and to be told that as mechanics they are skilful, resourceful, and competent would be unbelievable were not the evidence visible to corroborate the testimony of Mr. J. Van Kleef, the manager of the water works.

Besides the character of the workmen two interesting features of the Soerabaja water works are the construction of the rapid sand filter plant and the "nickle in the slot" meter in use for vending water from public hydrants in the street. The filter plant consists of concrete box filters protected from the weather only by a roof supported upon concrete columns standing between the filter units. The filters are exposed on all four sides, top and bottom. There is no pipe gallery and all of the parts of the plant are accessible and visible. It is an ideal condition which is attainable only in a climate where frost is unknown.

A UNIQUE METER

The Van Kleef meter, bearing U. S. patent No. 1,722,185 granted on July 23, 1929, is placed on the street hydrants which are used by

the poorer people whose houses do not contain services from the public water supply. The careless waste of water from these hydrants demanded relief which resulted in the design and installation of the Van Kleef meter. It operates on the tipping-bucket principle a certain number of buckets full being sold for the value of the coin for which the meter is set. When the proper amount of water has been delivered the supply of water is shut off and more water can be obtained only by inserting another coin in the meter. Generally five gallons are delivered for the smallest coin, the quantity being fixed by the size of the American 5-gallon oil can. The price of water sold in this manner is about \$1.10 per thousand gallons.

DUTCH RESEARCH LABORATORY

An experimental laboratory for research in water purification problems is maintained at Manggari near Weltevreden (Batavia) in connection with the Governmental Sanitary Laboratory and Research Station. The diversity of problems being studied there is indicated by the titles of recent publications, such as "Chemical Precipitation of Humic Pigments" by Dr. C. P. Mom, Director of the water research problems, "Examination of Water After Purification Through a Norite Filter" by Dr. M. Sardjito, and "Goitre and Its Control" by Dr. W. F. Donath. It was a refreshing experience to find such intense interest in water purification problems from a purely scientific viewpoint and to find that leadership in the search for Truth in water purification is not confined to the Western Hemisphere. The recognition which our Dutch friends give to American science should be reciprocated both in a spirit of friendliness and for the value of the Dutch discoveries. For example, Mom, in writing of his experiments on the precipitation of humic pigments, states:

Also in Miller's (U. S. Public Health Reports, 1925) experiments with the coagulation of synthetic humic acid by alum salts there is some resemblance with the clearing of the water at Bagan Si Api Api, but the fundamental differences, which Miller observes between the coagulation of colloid clay and of (synthetic) humic matter, both by means of sulfate of alum, were not found in our experiments.

and Donath, in discussing Goitre and Its Control, states:

Also in America the authorities take more and more interest in the control of goitre. . . . Extensive researches showed that of the United States the Great Lakes states had the highest percentage of goitre cases. Of the

numerous goitre research committees in the various countries, the ones in Switzerland and in Bavaria have collected the greatest material from which the extent of the affection may be deducted.

Norite is a proprietary compound used in water filters suitable for households and small institutions. It is concluded as a result of the tests and the price of norite which is 50 cents per pound that this method of water filtration is satisfactory where no reliable drinking water is available.

THE COUNTRY OF THE WHITE ELEPHANT

King Prajadhipok, absolute monarch of the remarkable kingdom of Siam, is a progressive ruler who is to be admired for his attitude towards public improvements and the advance of public works in his capital city, Bangkok. Besides many other public utilities Bangkok is provided with a waterworks which delivers filtered water to almost the entire city. The management of the waterworks is French, but the water filtration plant is equipped with Jewell rapid sand filters. The older filter building houses 12 units of the circular tub type cleaned with mechanical rakes. These older units have a capacity of 6,750,000 gallons per day. The new building, completed in 1930, contains 12 rectangular units of the Jewell type with a capacity of 10,750,000 gallons per day; giving a total capacity of 17,500,000 gallons per day to care for a population of 600,000. The water is obtained from a canal fed by the Menam Chao Phya river at a point about 25 miles above the city. The water flows through a protected canal which serves as a reservoir. This canal is about 5 miles long, 200 to 300 feet wide, and 20 feet deep with a capacity of 53 million gallons. The water is pumped into coagulating basins at the filter plant where it is coagulated with alum and then fed to the filters.

The entire area of the city is covered by the distribution system which contains about 75 miles of cast iron pipes ranging from 4 to 28 inches in diameter. Of the 400 public hydrants on the distribution system, 280 have 4-inch connections for fire fighting and the others are smaller to serve as public conveniences. These were provided by Royal Decree so that the poorer classes might have water free of charge. Although the population of the city is 600,000 there are only 8,000 customers on the books of the water works. All water sold to paying customers is metered and is sold on a sliding scale beginning at about 50 cents per thousand gallons. The income is sufficient to pay all of the expenses of the water works.

EVILS OF INTERMITTENT OPERATION

Intermittent operation is the rule rather than the exception in the larger cities of British India due to inadequate supply and high demand. Demand for water is high because the Indian bathes frequently for his bodily comfort and to satisfy religious beliefs which also require the Hindu to bathe in running water. In all cities there is a large proportion of the residences which have no interior plumbing. Residents in such houses secure their water from public hydrants in the streets. These hydrants are allowed to run continuously in spite of efforts of water works authorities to overcome the practice. It is the same difficulty which has been overcome in Soerabaja, Java by the installation of the Van Kleeef meter. Public opinion and the demand for running water would probably prevent this solution of the problem in British India as the Hindu is not at all bashful about taking his bath on the public street under the running hydrant.

Unfortunately intermittent operation does not cut down consumption in direct proportion to the number of hours operated per day. At Lucknow it was stated that the consumption had been reduced since operation on a 24-hour day basis had been started. Increase in consumption as a result of intermittent operation is due to the habits of the consumers. Water receptacles are placed under the hydrants and the hydrant is left open to run freely when the supply is renewed. When the unattended container is filled the overflow runs to waste. Shortly before the resumption of flow is expected water remaining in the receptacles will be thrown to waste to assure the collection of a clean, fresh supply. Under such conditions it is not difficult to understand how intermittent operation is not effective in reducing consumption.

CONTAMINATION RESULTING FROM INTERMITTENT OPERATION

An evil of intermittent operation is the contamination of the water supply by the alternate filling and emptying of the distribution system. When the pumps are stopped or the supply valves are closed a vacuum is created in the higher parts of the distribution system due to water being drawn off at lower points, and polluted water will be drawn into the pipes through leaks and through submerged services which have been left open. The flow of polluted water into the pipes is not confined to those points where there is a vacuum because the

pressure in the pipes may be so reduced that the surrounding ground water pressure will be sufficient to force polluted water into the pipes.

Another peculiar and rather unexpected cause of the suction of water into the distribution system is the high velocity of flow through the main pipes as they are refilling. Suction is created in branch pipes and services, the action being similar to that which takes place in a jet pump. This is brought out in a statement in the report of the Filtered Water Contamination Special Committee of the Calcutta Municipal Council, issued in May, 1929. In this report the following quotation is taken from the Local Government Board of England:

The liability of leaky water pipes to act as land drains to receive foul matters as well as land drainage through their leaks is not to be overlooked. Such leaky pipes running full of water with considerable velocity are liable to receive by lateral insuction at their points of leakage external matters that may be dangerous. The latter fact is not recognized so generally as it should be and ignorance of it has probably baffled many inquiries in cases where water services have, in truth, been means of spreading disease.

WATER PURIFICATION IN BRITISH INDIA

Rapid sand filtration is making inroads on the supremacy of the slow sand filter in India as it is in other parts of the world, but its progress is slow partly because of the difficulty of securing reliable and experienced operators. To vary the monotony of rapid sand and slow sand filters found almost universally in water purification plants it was refreshing to find a Puech Chabal filter at Cawnpore. Except for intermittent operation and its resultant evils the standards of water works equipment and operation in India are good. All important supplies taken from polluted or doubtful sources are filtered and the works of Calcutta and Bombay are models of excellence.

Increase in the favorable attitude towards rapid sand filtration is indicated by the recent progress in filter construction. At Delhi the slow sand filters have been abandoned in favor of rapid sand filters and at Agra a rapid sand filter unit was completed in 1930 to supplement the older slow sand filter. At Calcutta, however, where the water works have recently been extensively renovated the old slow sand filters were increased in capacity. Most filter plants are being operated to the full extent of their capacity without reserve and with little or no laboratory control. Algal growths in sedimentation basins and reservoirs is a common difficulty during the hot weather preceding the monsoon. This puts a load on the filter

plants with which it is difficult for them to cope and which demands greater skill in the operation of a rapid sand filter.

INTERESTING WATER WORKS STRUCTURES IN INDIA

The Tallah elevated reservoir in Calcutta, and the Tansa Dam and the aqueduct of the Bombay water works are three remarkable structures from a water works viewpoint. The Tallah elevated steel reservoir is 320 feet square and 16 feet deep, with its bottom 110 feet above the ground. The total weight of steel in the structure is 4,480 tons. Its appearance is striking; its economics questionable; and its influence on reservoir style in other Indian cities is remarkable because tanks of its pattern are numerous. The Tansa dam of the Bombay waterworks is one of the largest masonry dams in the world, but its fame is not widely spread. It is 9,800 feet long and at its highest point it is 135 feet high. The reservoir formed by the dam has a capacity of 35,600 million gallons and is the principal source of Bombay's water supply. The reservoir is located 55 miles from Bombay in an uninhabited district which comprises the watershed upon which the water is collected. The Bombay aqueduct, consisting of two 72-inch steel pipes 55 miles long, was completed in 1927 at a cost of approximately \$10,000,000. The quality of the water is such that it requires only chlorination, the chlorine being added at a point about 25 miles above the city. There are two chlorinating plants about one mile apart along the aqueduct, the equipment being in duplicate to assure uninterrupted dosing.

EUROPEAN WATER WORKS

Thousands of words would be required to describe European water works at all adequately. Progress in water works practice throughout the world has been due mainly to practice and experiment in the countries of Europe, hence there is much to be learned through a visit to the works and laboratories of Europe. A mere mention of some of the European cities and their water works problems will indicate the interest and diversity thereof. Paris has a dual water supply, one filtered through Puech Chabal filters and the other taken from the Seine and delivered without purification. The purification plant is under close laboratory control and the filtered water is of the highest sanitary quality. At Dresden the cultivation of bacteria for the removal of manganese is practiced successfully, 100 percent of the manganese being removed. At Amsterdam the water col-

lected from the sand dunes is highly impregnated with manganese which is successfully removed by multiple filtration depending both on aeration and biological action. At Altona the filters which were in operation in 1892 during the famous cholera epidemic in Hamburg are still in use. One acquainted with the history of sanitation and with the story of what these filters did cannot fail to be emotionally moved when gazing upon their placid surfaces which have saved so many lives the world over.

A study of the water works of Berlin furnishes a special course in iron removal. If memory does not fail me there are five iron removal plants, each of a different type, treating the entire water supply for Berlin. The water is taken from the ground at a depth of about 150 feet, from wells located on the environs of the city. After use the water (now sewage) is spread out onto the land of the nearby sewage farms, also in the environs of the city. Probably some of this water ultimately percolates into the wells again, but in a purified condition. It is an example of the "circulatory" system of water supply and sewage disposal, but the circuit is not quite so short as in some of our Lake municipalities which dump their sewage into the same body of water from which the public water supply is drawn.

What can be said in a few words of London's immense water works and at the same time not be misleading? The supply is taken mainly from the Thames river. It is stored in enormous and numerous reservoirs. The Queen Mary is the largest of these. Its embankments are the surrounding country and the immense size of this artificial lake is most impressive. Problems of algal growth, evaporation, seepage, pumping, purification, and all others are to be met in a study of London's water works; the largest and most interesting in Europe.

Liverpool, with its beautiful Lake Vyrnwy and dam located in north Wales; Glasgow which draws water from romantic Loch Katrine made famous in the story of *The Lady of the Lake*; and Edinburgh which draws its water from nearby hills and filters it through pressure filters in order not to lose the advantage of the gravity supply, are gems of interest and instruction in a water works tour of Great Britain.

CONCLUSION

Among the striking things to be observed in viewing the water works of the world is the amount of construction in progress; the

emphasis which is being placed upon quality and purification; and the growing favor in which rapid sand filtration is regarded. There is much to learn through a visit to distant water works and the hospitality met is warm, generous, unstinted, and international.

ADMINISTRATION AND FINANCIAL PROBLEMS IN GEORGIA¹

MACON, GA.

BY R. E. FINDLAY²

Many of those within the sound of my voice have doubtless heard their grandmothers refer to the "good old days" when there was a grand old man, kindly and sympathetic, known as the "family doctor," who was the clearing house for all the physical ailments, real and imaginary, that afflict the human race. During this period of generalization he probably treated many patients for cramp colic who died with what science later discovered was appendicitis. The old fellow meant well, but was attempting to cover too much territory. Still later the profession learned that it was better to know one thing well than have a smattering of many. Then dawned a new era—the age of specialization. The old family doctor has faded from the picture and in his place there are some half dozen specialists, each with a different function to perform. The forward march of progress in some other lines of endeavor has not been quite so rapid. There are many cities today owning their water works, municipal bosoms heaving with satisfaction and pride of ownership, yet operating this great utility as a department of the city government under the direction of a standing committee of two or more from an aldermanic board, having tenure of office of perhaps two years. With ever recurring elections the water works is made a political plaything and experienced men, specialists in their line, are forced to yield their places when patronage is dispensed by a new political faction as a result of the fortunes of war. Under such a system will this important of all public utilities, upon which the health of the community depends, get the consideration it deserves? I think not.

Financially speaking, every city is hard up. Looking backward, one can see a long line of lean years fading into the dim perspective, and for the future their gaunt forms stalk along the distant horizon.

¹ Presented before the Southeastern Section meeting, April 8, 1931.

² Secretary-Treasurer, Board of Water Commissioners, Macon, Ga.

The tax rate is too low adequately to provide for every need, so many corners must be cut in important appropriations and the water works must suffer. There is a demand for extensions; it takes money to make them. New equipment is needed; where is the money coming from? There is an obsolete distribution pump, with waning efficiency, that should be replaced with something modern. Your aldermanic committee tells you to stretch the old one through another year, as perhaps within that time the financial horizon may brighten. The water department is a revenue producer. Therefore, the temptation to divert funds arising from water sales is strong. The water department should not be fed on appropriations from the aldermanic board. There are too many emergencies that are possible, too many contingencies that menace efficient operation. Every dollar earned by the sale of water, or that flows in through this channel should be at the disposal of the water department and not diverted. In some cities where water revenue is paid into the city treasury, water rates have been increased for the specific purpose of boosting income to relieve, so far as possible, the advalorem tax. The law provides that funds for the operation and maintenance of municipal government shall be raised by taxation. Now then, when a municipality sells water at rates far in excess of the cost of production, plus a reasonable amount for extensions and improvements, the retirement of bonds and bond interest, and spends such excess for the support of other departments of the city government, such application of funds, in my opinion, constitutes double taxation and the practice will hardly stand the acid test of a legal investigation. The tax rate is fixed by law and cannot be increased without legislative sanction. Unfortunately, water rates, in many cities can be changed to meet the exigencies of acute situations, or if they happen to be fixed by statute, then the aid of the "service charge" is invoked—the monthly charge for a mythical service—to bolster the depleted treasury for the benefit of streets, sewers or something with which the water department has nothing to do. The ideal situation for the water department is to segregate it entirely from the municipal government and make it an independent, self-contained department or organization, to work out its own salvation and fulfill its own destiny. Administration under such conditions places the responsibility for management where it belongs. A specialized form of management, those charged with administration being unhampered by the regulation of other departments or being used as pawns in the game of

municipal politics. The greatest contributing factor to the health of a city or community is pure water. Some potable liquids will mix with politics, but pure water will not.

I have attempted to outline what, in my opinion, constitute the ideal conditions that make for the successful administration of the municipal water works and the methods of finance. Perhaps I can get in little closer touch with my subject by complying with a request to say something of Macon's problems and methods. We do not claim perfection, but have gotten, and are still getting mighty satisfactory results.

SITUATION IN MACON

In the early months of 1911 Macon's eyes began to focus on municipal ownership of water plant. A private corporation had handled it with varying success, once under the supervision of the court, through a receivership. Negotiations finally ended in a purchase, along with an issue of \$900,000 of serial bonds. These bonds sold at a handsome premium and the title to the water works passed to the city. A special act of the legislature placed this property in the hands of a commission of three, known as the Board of Water Commissioners. The term of office was fixed at six years, but the terms were not made concurrent. There is an election every two years and in the event a commissioner retires, the board is left with two seasoned men. These commissioners are charged with operation of the system, having absolute control, with authority to hire such help as needed, collect water bills, have their own banking connections, retire bonds as they mature, pay semi-annual interest and create a sinking fund. There is no connection with the city government, except that the city is made a customer. The venture, if I may call it such, was successful from the start, and has continued so. The plant was practically rebuilt and many extensions made. We have gone far beyond the corporate limits of the city and, in so doing, have, at times, been subjected to adverse criticism. Our commissioners take the position that pure water makes healthy suburbs, while healthy suburbs contribute to the general health of the community. One potent factor in these extensions is to increase revenue, for had operations been confined to the city proper the income would not have been sufficient to meet all demands, especially during the early years of operation. With no authority in our charter to borrow money, whatever was accomplished after paying the actual cost of operation

must be paid out of earnings. When the United States entered the World War a training camp was established in Macon and we were called upon to supply water. This meant about 7 miles of 14-inch pipe, the outlay for which was more than our treasury could stand. With no borrowing power, arrangements were made with a local bank to overdraw to the extent of \$100,000, subject, of course, to interest. The line was rapidly laid and the overdraft made good, in due time, without impairment to our general efficiency. One of our best assets is a thorough and complete system of accounting that enables us to know exactly what is being accomplished in a financial way. An audit is made at the close of each fiscal year and we know what our net earnings are.

Metering

A serious problem that confronted us three years ago was reaching a decision as to the best method of doing away with our flat rate water services. The board had adopted a resolution to meter the system 100 percent. It was then metered 66 percent, which meant the installation of 4000 meters. Property owners were notified to make application for meters by a fixed date. Many responded, but the majority did not. As we require the consumer, or property owner to pay for the meter we then proceeded, arbitrarily, to set a meter on every flat rate water service in our system. When the job was completed our pumpage dropped approximately 50 percent, indicating the enormous waste and loss through flat rate services. Collecting for these meters was rather tedious. Our cash price was \$17.00 for a $\frac{5}{8}$ -inch meter, or \$18.50 on time. Under the latter arrangement the down payment was \$3.50, and \$1.50 monthly, for a period of ten months. As a measure of protection purchase agreements were used, providing for retention of title pending payment of deferred installments. Very little difficulty was experienced in handling this matter, although of course, some defaulted in their payments. Whenever it became necessary to re-possess a meter the water service was discontinued. This proved a wonderful lever in securing satisfactory settlements. The prices quoted include, in addition to the meter itself, a meter box, fittings, repairs to a sidewalk pavement, labor for installation and maintenance. As already stated, the property owner pays for the meter, but the Board keeps up repairs. Let me say here and now that New York City, in her frantic search for new sources of water supply, will find her salvation and the solution of her troubles in

meters. In my opinion, New York does not need more water at this time if she will conserve what she already has available. The best ally any city can employ to this end is meters. Practically all the larger centers of population can learn something along this line from the smaller cities.

Where flat rate services are involved there is no incentive for conservation and the wanton waste of water is appalling. At the present time we have \$400,000 in bonds outstanding and are retiring them at the rate of \$40,000 per year. Beginning in 1935 we will take up at the rate of \$50,000 per year. The last series will mature in 1940. The interest this year is \$18,000. In handling our finances, it can readily be seen, we must make a reasonable profit on operations, otherwise we cannot pay bonds and interest and make extensions and improvements. During our last fiscal year, after taking up \$40,000 in bonds and paying \$19,800 bond interest, there was a net profit from operations of \$75,540.26. Our auditor's report shows cash in bank, subject to check, \$12,666.11, and \$125,000 in certificates of deposit drawing interest.

Our water rates will compare favorably with other cities in Macon's class. Our highest rate inside the city is 25 cents, the lowest 6 cents per thousand gallons. When all outstanding bonds have been retired there will be substantial reduction in rates. In the matter of finances our Board takes the position that water works funds belong to the people, and, therefore, are trust funds and the banks that handle them should be required to give bond. No bank will refuse to do this if it is made a legal requirement. We have been through three bank failures and the fact that we held security saved us a total of \$76,000. One of the things we need in Macon is an amendment to our charter making unpaid water bills a lien against the property served. There is no reason why losses should be incurred. Every citizen is entitled to the lowest rate that can safely be fixed. If we are to sustain losses through our accounts receivable, provision must be made to charge them off.

Our Board believes in efficiency and economy, but they do not advocate economy at the expense of efficiency. They believe in good salaries, which means satisfied and efficient help. Group insurance is furnished employees at the nominal rate of 60 cents per thousand per month. The excess is paid by the Board. In conclusion, permit to say that we are thoroughly committed to the policy or doctrine of specialization in water works operation, with full and complete

authority to those who must assume the responsibility for whatever measure of success or failure may be achieved.

THOMASVILLE, GA.

BY D. RHETT PRINGLE³

In beginning a discussion on financial and business transactions, whether in the utilities, or any other commodity, it is safest to begin at the end. The test of the whole program is the balance sheet. If there is no item of earnings to add to your surplus at the end of the auditing period, in my opinion, in French parlance, a "change of cabinet" is indicated. No industry can survive without profits.

In the Thomasville situation, very strict accounts are maintained, separate for the two services—water and electricity—the accounts being so sub-divided that it is readily determined for what purpose the costs apply. In our Statement of Operations are shown the items: Income, Service Sales and from Merchandise; Operating Expense, Maintenance Costs and Depreciation.

For making up the balance sheet we must, of course, have the property accounts properly listed, and the reserve for depreciation set up.

The accounts conform as closely as practicable to Uniform Classification of Accounts for Utilities as prepared for The National Association of Railway and Utilities Commissioners. This does not mean that we show on our balance sheet each of the 120 accounts listed by the above classification. In our system, the balance sheet shows 28 accounts, but due to our limited operation, this is complete. We believe that all water works, power and gas plants should conform as closely as practicable to the Classification, as it is the result of thorough deliberation by nationally known accountants, and must be right.

As regards the matter of financing capital expenditures in a small utility, we must admit that at times this becomes arduous. In Thomasville, the praise should go principally to the directors of our City, the City Council, and especially to the Chairman of the Water and Light Department, for he has served as such for fourteen years and is still going.

For this period of time the City Government has maintained a policy of separate financing for its utilities, under the leadership of our

³ Superintendent, Water and Electric Department, Thomasville, Ga.

Chairman and the Cities Committee, it has been possible to finance capital investments as large as \$100,000 from earnings of \$180,000 over a period of 24 months. In this manner we have been able to build an industry up from a value of \$41,000 to \$478,000 in a period of 25 years. No city or town of more than 1000 people is too small but that this business may be made profitable. The business end is the most important part. A small town water and lighting plant needs no elaborate set of books. For ten years in the Thomasville plant I made up my own books, but although they were elementary, they indicated closely whether there was a profit or loss in each period of operation. Even now, we do not maintain every detailed account as carried by the large utilities. If we did, our bookkeeping would be top heavy, but we do follow the big fellows just as far in this line as our business demands.

For your own protection and for the satisfaction of your stockholders I believe accurate bookkeeping and financing is demanded. In Thomasville instead of calling them "consumers" we call them "customers." We try to impress the customer with the fact that the business is dependent upon his patronage for its success. We have no competition such as the grocer, or other merchant has, but we work for the customer's business as though we were afraid we would lose it. Our meter readers and line crews and our clerks are made to forget they are working in a monopolistic business. Sometimes it is embarrassing—as when the lady wants the lineman to "watch out for baby while she runs down to the A & P", but it pays. Last year we had at least two customers call up and say that they believed their bills were in error—too small. It required meter tests and much conversation to prove to them that they were paying to the city all due.

NEW CONSTRUCTION

The most interesting part of the utility business is new construction and it is probably the easiest place to lose money. In Thomasville, before launching a job three conditions must be met:

- (1) The design must be complete, preferably by a consulting engineer.
- (2) There must be an economic need for the improvement.
- (3) The financing must be arranged.

There are times when there is a certain amount of public demand for an improvement. An engineering survey will show you whether

the proposition will succeed or fail, and financial arrangements must be concluded before a start is made.

I believe few failures of water works systems may be laid to politics only. Whatever happens in the system must, 90 times out of 100, originate with the superintendent. It may be a fault of either omission or commission, but it is still with the superintendent.

We are employed for a supposed ability which we should possess. If we are not able we should not stand by and blame the politicians. Politicians are both good and bad. You find them in every walk of life. The wholesale grocer practices politics in his business— if it is good politics, he succeeds. Likewise the manufacturer's business, if he would only admit it is a large part politics. The water and light business will succeed if good politics are practiced, and will fail otherwise.

GRIFFIN, GA.

BY H. P. POWELL⁴

We are 100 percent metered in both the production and distribution ends of our system and the man that thinks he can make a success of a property which is in part or all on flat rate system is entirely wrong, for he will either be losing money or, if he is showing a profit, he is making one set of customers pay for the wastefulness of the other set.

The only uses of water which we have that are not metered are the fire department and that which is used for sewer flushing.

At the end of each month the chief of the fire department gives me an estimate of how much water he has used during the month and at the end of each week the sewer flusher gives me a report showing how many flush tanks he has flushed during the week. With these two reports it is easy to arrive at a very close estimate for the water which is used for fire purposes and sewer flushing. All other water that leaves our mains with our knowledge is metered, except the leakage.

In the production end of the business we are fully metered and can always pick up any waste that may be going on there.

With this system of metering we keep our unaccounted for water at about 18 percent.

We keep check on all large users and any unusual dropping off in

⁴ Superintendent, Water and Lights, Griffin, Ga.

consumption is immediately investigated to make sure that the meter has not slowed down or stopped.

In the matter of collection of bills we show no favorites. A city ordinance provides that a cash deposit is required of a tenant, unless the contract is guaranteed by the landlord. The ordinance also requires that all bills are to be paid by the tenth of the month or the customer is to be cut off. Just as soon after the tenth as it can be done the cut-off list is made up and sent out for execution and this list carries every customer who has not paid his bill. When a customer is cut off we charge a cut-on fee of 50 cents before they are placed back on service.

I personally purchase all materials and supplies and we purchase in quantities sufficient to get the best discount for our requirements. We discount all bills on the fifth of the month and we have an agreement with those from whom we purchase that we will pay all bills received by ten o'clock on the morning of the fifth and take the cash discount on all bills which have accumulated since the fifth of last month. This arrangement does away with the necessity of passing bills through for payment all through the month.

The cost book is kept up to date and we have a complete record of all costs for the past nine years. We add 5 percent to the delivered cost of all materials to cover the handling charge. After this 5 percent has been added we call this the total cost and all materials and supplies are charged out to our various accounts at "total cost."

I personally approve all charges covering labor as well as materials and supplies and I have found this the only sure way of getting all charges into the correct accounts and also keeping close check on costs of everything going on in the department.

In the production department our daily log sheet shows all details of the day's operation. Should a motor or pump go wrong and it was taking too much power for the pumping this would be caught not later than the next day. Any other irregularity in our operation would also be caught in the same way.

We have a schedule of flat charges for making taps, but our charges for this service are entirely too low. For instance, we charge only \$10.00 for a $\frac{3}{4}$ -inch tap and this means we get only \$10.00 for bringing the service from the main and setting the meter at the curb line. If the street is wide and paved you can easily see where the department will come out from a financial standpoint.

We allow no one but our own men to tap our lines and the system

belongs to the department up to the point where the water has passed through the meter.

We make no assessments or charges of any kind for laying mains and the entire cost is paid by the department and carried to capital account.

In the matter of service we keep sufficient men to keep the work up to the minute. We average about one hour from the time a contract is signed for water, where the service has once been established, until the water is turned on. If a tap is to be made we try to make the tap the same day we get the order. If it cannot be finished the day the order is given we finish it the next day if possible. Of course, we cannot always do this, but it is the standard to which we try to work.

We are very liberal in all dealings with our customers, but we do insist that all bills be paid promptly. All employees must be courteous at all times. This means that they must be courteous to one another as well as to the public. We have no place in our organization for a grouch.

Our bookkeeping system is quite simple. In fact, it is almost too simple and we now have an auditor working on a new set of books that will enable us better to analyze our operations. We do, however, analyze our accounts and at the end of each month a report is made out which shows where our money came from and how it was spent. For checking operations from month to month and year to year all accounts are also shown in percentages of the total.

For the proper operation of any plant I believe it is absolute necessary for the man in charge to know his system, his men and the details of his operations. By this I do not mean that an expensive set of records are necessary, but it is necessary that the important items of operation be definitely known month by month and by giving careful consideration to each item it will be possible to get the very best results under given conditions.

DISCUSSION

MR. MENG:⁵ We have a curb cock by which the water may be turned off and the consumer has no right to go into the box or meter unless he has permission from the water department. In case of flooding a house we would excuse a plumber for using this curb cock.

⁵ Superintendent, Water Works, Winnsboro, S. C.

I believe the company should own and have possession of the equipment to the curb. We find it a good rule.

J. E. GIBSON:⁶ I should like to ask how one keeps the man who has a vacant lot from demanding a service and also to control the size of the service. In other words, a development company lays out a site in a town of 30- or 40- foot lots. There is not a house situated on it. It may or may not be developed. He demands that the water department lay out a main there and put a service into each lot. You may have invested a few or several thousand dollars.

MR. MENG:⁵ We have never had a development like that. On the other hand we have had some small ones cut into lots and they demanded that we put in water. We told them we would put it in when there is anybody on it. We will guarantee that we will have a main there by the time they have the first house built, and as the development builds up we furnish water. But we do not extend until we can obtain revenue. He can legally demand service when houses are ready, but not for vacant lots. Fortunately, our corporate limits do not extend so far and the system has been already installed, therefore, we do not have much of this sort of thing. As the town grows it might be a good thing to own the taps.

MR. GIBSON:⁶ I find that the matter of services is in chaos. There is no universal rule either as to price, charges, costs, ownership, what is and what is not done, and as to materials used. In those sections where water departments are allowed to charge a tax it is all right for the company to extend its mains, put in services, own and pay for them, but where the law does not permit you to make a frontage charge for unused or undeveloped property, I question whether it is the part of wisdom and good finance to extend mains. There may be conditions under which it is advisable to extend mains, but I do not believe it is warranted at any time to put in services in advance of actual demand, because no one can predict what the development is going to be.

We have had some trouble in extending service at Charleston. Those of you who visited Charleston fifteen or twenty years ago know that we had streets mostly of Belgian block and cobbles. We have no

⁶ Manager and Engineer, Water Department, Charleston, S. C.

rock in Charleston or vicinity. The Belgian block was all we could get. About ten years ago we undertook a very energetic venture to pave the streets, and our municipality ordered streets paved all over town. The town is pretty well paved now. Some of them have been paved and they are not developed. The cost of paving them is in my mind a financial mistake, but they insist on the water, gas and telephone service being put in in advance of any other improvements. We put in mains. The gas company even went so far as to put in some services. Now it is logical to want those things. It looks much better. People begin to look around and want to invest some of their surplus funds. If a street is paved they will buy a lot quicker and they want service connections. It is put right up to us. We are digging holes in the pavement. We cut a hole 2 by 3 feet and put in the service. Somebody riding in an automobile gets a bump and we have claims against us. We have spent thousands of dollars paving these streets and now the water department is breaking them up. In making the assessments the law was not drawn to include the cost of these services as a part of the cost. We have 400 or 500 services that are lying idle, costing anywhere from a few dollars to as high as \$50.00 with no return on the money whatever. I think that services ought to be paid for by the property owner. But how are you going to make the property owner pay a reasonable return on the investment for the service whether he uses it or not? All the water company then has at risk is the hazard of maintaining the service in the street, and that is now no small item.

MR. POWELL:⁴ I do not think that the services should be installed until they are paid for. You may have an investment tied up for a long time. A scheme that I have used to eliminate some of this trouble is to put two 2-inch lines in our streets. We have the account tied up and we are getting nothing on it, and the only money that we can get from it is when we make the tap for which we get \$10.00. We have found that it is very unsatisfactory to go ahead and install services until there is an actual demand. We are no different from the rest of the cities. We are simply operating under a custom that started long ago and there is not enough moral courage to change it. The city commissioners can pass on it and we can then do whatever we want. As to the ownership of services my experience has been that the only way that you can get satisfaction is to own the service up to the point where the water passes through the meter. We would

not allow anyone to use our curb cock. If a man operates our curb cock without permission, we make a case against him.

J. H. McLURE:⁷ We have a different method in Chester. The city does not put in any services at all. Of course, the water works in full is a municipal franchise. The plumbers put in all the services and tap the mains. The property owner pays them for it. The plumber is required to give bond protecting the city against damages for any injury that is done and to guarantee that the street will be repaired and put in the same condition that it was originally. After the service is put in, simply by custom, the city assumes the ownership of it and maintains it out to the meter, so that we have no money tied up in services at all, except on municipal property like the city hall. Before a street is paved the abutting property owners are notified that they cannot cut the street for ten years. If they want to put in any services it is up to them to put them in and quite a number of them have done so. All the property owners and citizens have an interest in the city, and we have found that we are working exceptionally well there.

MEMBER: In reply to Mr. Gibson and Mr. Powell that the city should own these services outright, I would like to ask Mr. Powell what type of pipe he uses.

MR. POWELL: We use some galvanized, but mostly 2-inch cast iron.

MEMBER: That would work pretty well in a residential section, but what would you do in a business section?

MR. POWELL: We make them upon their order. Whatever size it is. We cut the pavement.

W. W. POINTER:⁸ We have a similar plan at Clarksdale. We do not allow the plumbers to do any tapping there at all. A $\frac{3}{8}$ -inch tap is the smallest we make and charges are based upon the size of the tap used. The customer has no rights in the property after the tap is made. We control it. We do not allow plumbers the privilege of tapping the mains at all.

⁷ City Manager, Chester, S. C.

⁸ Superintendent, Water Works, Clarksdale, Miss.

E. C. MORRISON:⁹ Mr. Powell read a very interesting paper, but he did not tell us how the revenue and the expenditures compared.

MR. POWELL:⁴ I purposely did not try to give you that, because we have not finished operations for a year in our new water plant. We just last year put into operation a new filter plant changing from a deep well system, but for the year 1930 the gross water sale showed \$7,783 net profit. We handle electricity, too. We put \$80,000 net in the bank out of \$130,000 gross revenue on our electric plant. That is operating profit, although in addition to that we furnish about \$20,000 worth of free service to the city. We just include that in our operating expense.

⁹ Superintendent, Water Works, Bennettsville, S. C.

THE NEW FORT WAYNE WATER SUPPLY¹

By R. L. McNAMEE²

The present municipal water supply of Fort Wayne is drawn from wells and pumped into the distribution system at a number of independent stations situated throughout the city. The system has grown from a single station with gravel wells about 70 feet deep, to a system of deep rock wells, some of which are over 600 feet in depth. The addition of new wells and pumping stations at different points in the city kept pace for a time with the city's growing water supply needs, but for several years past the development of additional supply has not been as rapid as the city's growth in population and industry. It is now apparent that the practical limit of this form of development has been reached, while at the same time the water needs of the city and its industries, already beyond the capacity of the present system, are steadily increasing.

The total dependable and continuous yield of the present system is indicated to be not over 12 m.g.d., and there is convincing evidence that the yield of the field is slowly diminishing on account of the heavy overdraft made upon it by both city wells and industrial wells. If some further developments are not made soon, the yield from the present city wells may be expected to diminish slowly until an annual average yield of not more than 8 m.g.d. is reached.

The water drawn from the wells is excessively hard and some of it contains objectionable amounts of iron, and, in a few cases, hydrogen sulfide. Pollution from surface drainage has required the shutting down of one station at times. The hardening constituents consist almost wholly of mineral compounds of lime and magnesium, which have been dissolved from the rocks and soils through which the water has passed in its long journey from the spot where it fell as rain to the city wells. The average of the total hardness of the water from all wells is about 544, of which about 344 p.p.m. is carbonate hardness and the remaining 200 p.p.m. non-carbonate hardness. This is an

¹ Presented before the Indiana Section meeting, February 27, 1931.

² Hoad, Decker, Shoecraft and Drury, Consulting Engineers, Ann Arbor, Mich.

excessively hard supply as municipal supplies go. The burdens which it imposes upon both house-holder and industry are keenly felt and the citizens of Fort Wayne have indicated a desire for a softer supply.

AN ADEQUATE SUPPLY FOR FORT WAYNE

The Federal census for 1930 determined the population of Fort Wayne at slightly over 115,000 people. A careful estimate of the future growth of the city indicates that the city may expect to have a population slightly in excess of 150,000 in 1940, 175,000 in 1945 and 200,000 in 1950.

TABLE 1

Estimated future water requirements, Fort Wayne

	YEAR			
	1935	1940	1945	1950
Estimated population.....	133,320	153,860	177,090	203,300
Daily per capita consumption rate, average for entire year; gallons per capita per day.....	102	104	105	106
Daily total pumpage, average for entire year; million gallons per day..	13.6	16.0	18.6	21.5
Average daily pumpage during maximum month; million gallons per day.	17.0	20.0	23.2	26.9
Total pumpage on maximum day, million gallons per day.....	21.8	25.6	29.8	34.4
Maximum hourly demand rate for all purposes, including N.B.F.U. requirements for a maximum fire; million gallons per day.....	54.6	62.1	70.5	79.6

In the past decades the development of the industrial life of the city and the growth of its commerce and trade have been even more rapid than its increase in population. It is generally recognized that Fort Wayne possesses many fundamental advantages as an industrial and commercial center, such as its wealth of railroad facilities, its two independent sources of dependable and low priced electric power, and its great natural benefits in the way of topography and excellent geographical location. Its present standing is well established and its future position seems assured.

The use of water in Fort Wayne has been limited in the past by the inadequacy of the supply and the shortcomings in its quality. The

average daily rate of consumption for 1929 is only about 86 gallons per capita. This low per capita rate is due in considerable degree to the fact that the water consumers have not had all the water they would have used had it been available. The generous use of water on lawns and gardens has been discouraged rather than promoted, the quality of the supply has been hard and in some cases objectionable in other respects and the pressures have been inadequate and uneven. For the same reason the industrial use of city water has been comparatively small and many industries have developed their own private supplies instead of taking water from the city mains.

For the future, under conditions in which an abundant supply of soft water will be available under good pressures, the per capita use of water may be expected to be somewhat greater. The estimated water requirements of the city for the next twenty years are summarized in table 1.

AN ADDITIONAL SUPPLY FROM THE GROUND

The present city supply of ground water is taken from a thin deposit of magnesian limestone, locally called "water lime." The catchment area of this water lime, and therefore the area which contributes more or less to the city wells, appears to be about 400 or 500 square miles in extent, and to reach in a crescent shaped area from near Fort Wayne to near Decatur, Indiana, with the outer arc of the crescent passing through Huntington. This tributary area is large enough to supply considerably more water than the quantities which are now taken from it by the wells at Fort Wayne, but the cost of developing groups of additional wells, at points far outside the city and far enough away to avoid interference with the present wells, is so high as to put any such plan out of consideration.

The water is of poor quality, having a total hardness of about 550 p.p.m. The water could be softened but only with difficulty and at great expense. The nature and quantity of the hardening constituents are such as to require costly amounts of chemicals for their removal. The cost of pumping and conveying the water from a number of widely scattered wells and pumping stations to a common center, where softening and iron removal could be accomplished, and the repumping through the distribution system would be very heavy. For these reasons it must be concluded that the rock well sources cannot be made to yield an enlarged and wholly satisfactory supply of water for Fort Wayne needs.

The existence of many deposits of water-bearing sand and gravel in the glacial drift of northern Indiana encouraged the hope that some large water supply source of this nature might be discovered, and a very careful and extensive survey of the gravel bed areas in the vicinity of Fort Wayne disclosed the fact that such water-bearing gravel areas do exist, but their size and extent are so limited that a dependable continuous yield of not much more than 5 m.g.d. might possibly be developed. The quality of the water from the gravel is much better than that from the rock wells, but it still must be classed as excessively hard. The average total hardness is found to be about 350 p.p.m., of which about 300 appear as carbonate and about 50 as non-carbonate hardness. The inevitable conclusion from all the extensive and thoroughgoing surveys which were made of ground water resources in the vicinity of Fort Wayne is that all of the water from underground sources is excessively hard, some of it with objectionable quantities of iron; that the city and industrial wells have already developed and are now utilizing as much as the deep rock sources in the immediate vicinity can be depended upon to yield; and that the scattered gravel beds of the region are not worth developing except in a limited way and for local uses.

SURFACE WATERS

After the disclosure of the unfavorable conditions for the development of additional supplies from ground water sources, attention was directed to the available surface water sources.

Fort Wayne is situated at the junction of the St. Marys and St. Joseph Rivers which form the Maumee. A map of these rivers and their watersheds is shown on figure 1. From the junction, the Maumee flows in a northeasterly direction to the western end of Lake Erie. The watershed, including the City of Fort Wayne, has a sewered population equal to about 72 persons per square mile of area, with 80 per cent of this population concentrated just above the only feasible point of intake. This condition is so highly undesirable as to put Maumee River out of consideration as a source of supply.

The St. Marys River, the southern branch of the Maumee, rises near the town of St. Marys and the Grand Reservoir in Ohio. From here it flows in a general northwesterly direction through Ohio and Indiana to Fort Wayne. The area of the drainage basin of St. Marys River at the Fort Wayne city limits is about 870 square miles. Upon this area there is estimated to be a total population of about 52,000

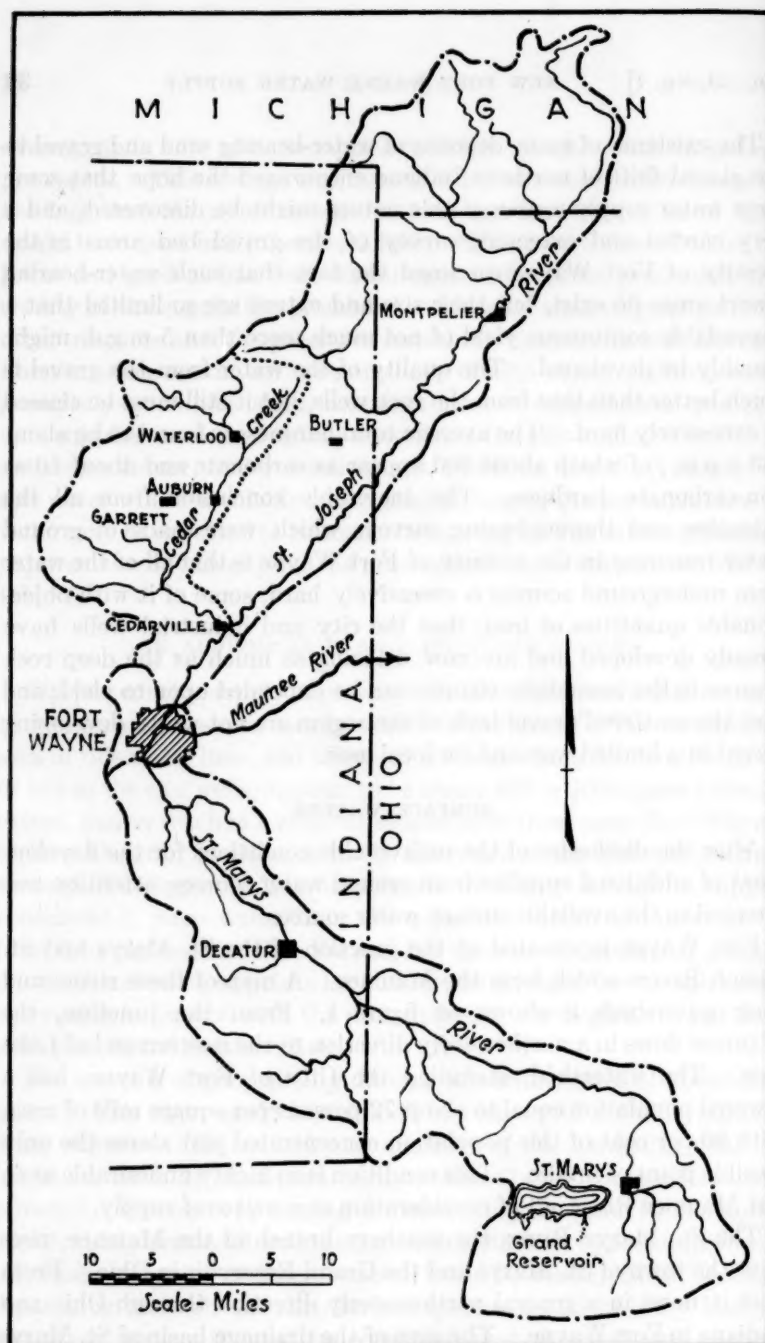


FIG. 1. FORT WAYNE, INDIANA
Water Works Improvements. General Map of St. Joseph and St. Marys Rivers.

persons, of which some 12,200 are served by regular sewerage systems, making a sewered population of about 14 per square mile. The water of the river during the low water season has a total hardness of about 280 p.p.m., of which 135 are carbonate and 145 are noncarbonate hardness. The discharge of the river is known to vary greatly and very few definite and dependable data are available. It is estimated that the river flow occasionally drops as low as 25, with an average of 30 or 35 cubic feet per second for a minimum month.

The St. Joseph River heads in a number of spring fed lakes in the southern part of Hillsdale County, Michigan, and Steuben County, Indiana. From the headwater district the river courses in a general southwesterly direction to Fort Wayne. The only important tributaries are those from the west, of which Cedar Creek, joining the main streams at Cedarville about 8 miles north of the city limits of Fort Wayne, is one of the principal ones. St. Joseph River has a total watershed area, measured north of the city limits of Fort Wayne, of about 1,110 square miles. Upon this watershed is a sewered population of 17,000 persons, equivalent to about 15 per square mile. The quality of the water in St. Joseph River as it enters the city shows a hardness of about 300 p.p.m., of which 260 are carbonate and 40 are non-carbonate.

The watershed of St. Joseph River above the junction of Cedar Creek has an area of 783 square miles. This area, comprising about 70 per cent of the total drainage basin of the river at Fort Wayne, contributes at least 80 per cent of the dry weather flow in the river, partly on account of the more absorptive nature of the soil in the upper reaches, but also because of the steadying effect of the large number of lakes. The watershed above Cedar Creek has but two sewered municipalities upon it, having together a total population of slightly over 5,000 persons, equivalent to less than 7 per square mile of watershed. The flow in St. Joseph River above Cedar Creek is estimated from recent gaugings to have an average rate including flood discharges of about 470 cubic feet per second for the entire year. The rate may be expected to drop as low as 60 cubic feet per second for an occasional dry month and as low as 50 cubic feet per second for a day or two. The water of the St. Joseph above Cedar Creek is much better in quality than that below the junction. Above the junction the total hardness is about 275 p.p.m., of which 240 are carbonates and 35 are non-carbonate hardness. The water of Cedar Creek, which brings down drainage from the sewered cities of Auburn,

Garrett and Waterloo is much worse, showing a total hardness of 345 p.p.m., of which 270 are carbonate and 75 are non-carbonate. The water above the junction is thus shown to have less than half the non-carbonate hardness of that below the junction. The very extensive surveys and studies and analyses which have been made of these surface waters cannot be adequately described here, but from the results of this work the following conclusions were reached. Maumee River would furnish a supply sufficient in quantity for Fort Wayne, but it must be eliminated from consideration because of the pollution it bears. As between St. Marys and St. Joseph Rivers, the latter is preferable from every point of view, and St. Joseph River above Cedar Creek is from every consideration the best source available. The area of the watershed of this upper part of the St. Joseph basin is sufficient to supply the needs of the City for an indefinite time in the future, provided one or more additional impounding reservoirs are built as the demand becomes greater. The population on the watershed is comparatively small and is widely scattered over the entire watershed in small villages and rural homes. The quality of the water is fundamentally good and the surrounding conditions make it easy to protect and conserve this supply for future use. The water can be made entirely suitable for municipal use by standard methods of filtration and softening, and at reasonable cost.

THE VALUE OF WATER SOFTENING

Although the water of the St. Joseph River above Cedar Creek is only about half as hard as the water from the present city wells, it is still hard enough to justify amply the small additional expense of softening. In table 2 the water proposed to be used for Fort Wayne is compared in hardness with the waters of other rivers which are used as sources of water supply by other cities and which are softened by them before distribution to the consumers.

The science and art of water softening on a large scale have been greatly improved in recent years while the cost of the treatment has materially diminished. The water of the St. Joseph River above Cedar Creek presents no serious problem in its softening. It is, in fact, of such character that it may be softened to a satisfactory degree by the use of lime alone without employing the more costly treatment with soda ash or zeolites.

The value of softened water is readily understood and appreciated by the industrial consumer for its savings in steam generation,

laundry work, dye work and other processes in which the natural hardness of water has a detrimental effect, but it is also of great value to the individual householder and the savings which will result from the softening of water on a municipal scale can be easily shown.

The cleansing action of soap in water requires first that the hardness of the water be neutralized by the soap. This is a commonly understood fact, for a hard water is known to require greater quantities of soap than the soft water. Until the hardness of the water has been neutralized by the soap no lather can be secured to do the

TABLE 2

CITY	SOURCE OF SUPPLY	HARDNESS OF WATER, BEFORE SOFTENING, DURING ORDINARY LOW- WATER STAGES OF THE RIVER, IN P.P.M.		
		Total hardness	Carbonate hardness	Non-carbonate hardness
Fort Wayne.....	St. Joseph River*	275	240	35
Defiance, Ohio.....	Maumee River	230	170	60
Piqua, Ohio.....	Delaware River	260	230	30
Grand Rapids, Mich.....	Grand River	260	210	50
Newark, Ohio.....	Licking River	270	200	70
Flint, Mich.....	Flint River	275	225	50
Springfield, Ill.....	Sangamon River	300	255	45
Columbus, Ohio.....	Scioto River	300	190	110
Saginaw, Mich.....	Saginaw River	300	180	120
Midland, Mich.....	Tittabawassee River	350	170	180

* Softening proposed.

actual cleansing. It is conservatively estimated that on the average every individual uses at least one gallon of water for cleansing purposes each day, or a total of 365 gallons per capita per year. Using the water from the present rock well sources in Fort Wayne with a hardness of 544 p.p.m., and assuming that the water is softened by no other means, each individual would thus use about 50 pounds of soap per year. The average retail cost of soap may be fairly estimated at 12 cents per pound, so that the total soap cost may be estimated to amount to about \$6.00 per capita per year.

The total cost of operation and the fixed charges upon the investment of those parts of the proposed new filtration and softening plant at Fort Wayne which effect the processes of softening are estimated at about \$120,000 per year. This plant will have a capacity sufficient to serve the city until it reaches a population of 150,000 persons. At that time the cost of softening will thus amount to about 80 cents per capita per year. In the early years with a population of about 120,000, it will be about \$1.00 per capita per year. The water produced by this plant will have a remaining hardness of approximately 100 p.p.m., and every gallon of the water produced will be reduced to this hardness. The use of soap with this softened water to the extent of about a gallon per capita per day will amount to about $8\frac{1}{2}$ pounds of soap per capita per year, which at 12 cents a pound will cost about \$1.00. The cost of general softening, \$1.00, plus the cost of soap, \$1.00, thus bring the total cost to the individual to an amount of \$2.00 per year as compared with the \$6.00 per year, if no means of softening other than soap are employed. In this comparison it must be borne in mind that, with the use of the municipal softening plant water, the entire volume of water is reduced to a hardness of 100 p.p.m. so that the benefits of the partially softened water are available to every consumer upon opening the tap. These benefits calculated in dollars and cents to the industrial consumers would show a much greater proportional saving. There need be no hesitancy in making the statement that municipal water softening in the ordinary case will pay for its cost several times over.

THE PLAN FOR THE NEW SUPPLY

The plan of development for the new water supply of Fort Wayne involves the impounding of the excess flow in the St. Joseph River above Cedar Creek, the bringing of the supply from this point a distance of about ten or eleven miles to the city, the operation of a central purification and pumping plant in the city and the distribution of the purified water from this point to all parts of the city under higher pressure than those now used.

The up-river station at which the water will be taken from the river and pumped into the supply main will consist of a low-head dam and small pumping plant with their various appurtenances and equipment. The elevation of the dam will be slightly above that of the down-town plant but not sufficiently so to eliminate the need for low-head pumping. The dam will create and maintain an excellent river

pool for the intake and will impound sufficient water to insure an adequate supply to the city until such time as the purification and pumping plant will have to be enlarged. When this becomes necessary additional impounding reservoirs may be built further up the St. Joseph to store water and feed it down to the lower dam as required.

The supply main through which the water will be delivered from the up-river station to the purification and pumping plant will be laid for the most part along public highways in the most feasible direct route. The first installation will have a capacity of about 24 m.g.d. and will be furnished with gates and cross-connections at suitable intervals so that it may be made to work in harmony with another main to be laid alongside it at a later date when a larger capacity is needed.

The down-town plant will be built on city property at the junction of the St. Marys and St. Joseph Rivers. The general layout plan is shown on figure 2. The water will be received at the mixing tanks, in the chemical building at the north end of the plant, where it will be quickly mixed with the lime and alum employed in the softening and purification processes, and immediately passed on to the coagulation tanks. In these tanks the water will be kept in motion by slowly rotating arms for a period of about an hour during which the softening reaction is allowed to take place. In this process the hardening constituents of the water and the lime and alum, which were mixed into it as purifying agents, will interact and form insoluble matter which is coagulated into larger fragments. From the coagulation tanks the water will flow into clarifiers in which the heavier and more easily settled material will be precipitated, and from which the settled precipitates will be continuously removed and pumped away. The finer and lighter particles of sediment, which require a longer period of time in which to settle out, will be removed in the final settling tanks. These tanks will receive but a small part of the sludge and will be emptied and cleaned occasionally as necessary.

After passing through the settling tanks the water will be stabilized by having carbon dioxide gas pumped through it. This stabilization process will prevent any damaging incrustation of the filter sand and will insure against any after-deposits of lime carbonate in street mains and house plumbing. The plant will be so designed that the excess lime treatment with secondary carbonation may be employed.

After leaving the settling and carbonation tanks the water will be

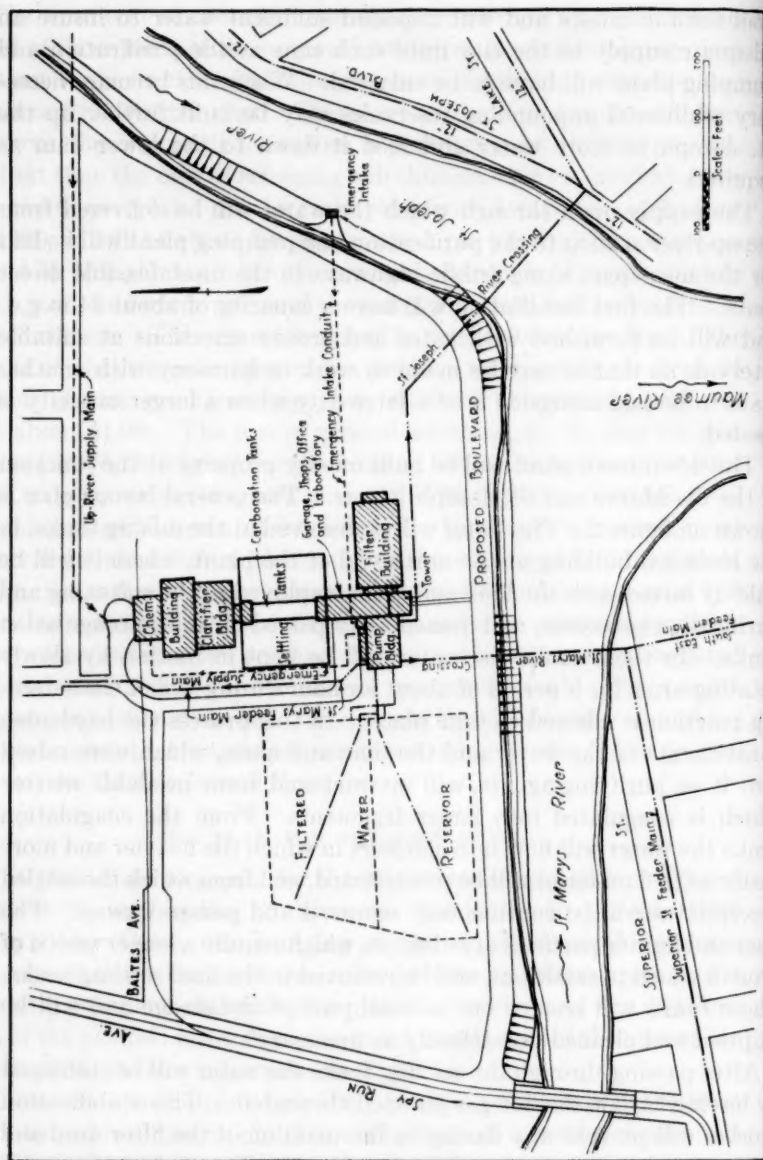


FIG. 2. FORT WAYNE, INDIANA

Water Works Improvements. General Layout Plan of Three Rivers Filtration and Pumping Station.

filtered through rapid sand filters. The first construction will have a nominal capacity of 24 m.g.d. The effluent from the filters will be carried in underground pipe lines to the filtered water storage reservoir, an underground concrete tank having a holding capacity of approximately 20 million gallons. The entire structure will be below ground covered with earth forming a broad and level lawn. The high-pressure pumps will draw their supply from the filtered water reservoir and pump it to the city through the feeder mains to meet the demands for water.

The central part of the main building will have space for offices, chemical and bacteriological laboratories, shops and garage. The wash-water tank for holding the supply of water used in washing the filters will be housed in the upper part of the tower of the building entrance.

The building is to be made an architectural monument. The design is based on Indiana limestone for the exterior with a structural framework of reinforced concrete and steel. The design will take full advantage of the favorable setting upon which the plant is to be built and will greatly enhance the beauty of the rivers and park in its vicinity. The main entrance to the plant will be from a lighted roadway along the river bank. The grounds between and around the structures will be graded up, landscaped and planted in harmony with the building plan.

The estimated cost of the proposed improvements, including the up-river dam, raw water supply line, the down-town purification and pumping station and the feeder mains, is about \$2,750,000. The construction is to be financed mainly from a bond issue which was authorized by ordinance of the Common Council of the City of Fort Wayne December 29, 1930, and was approved by the Public Service Commission of Indiana on December 31, 1930. The interest and bond retirements and the operating costs of these improvements are to be paid for out of water works revenue, for which purpose a readjustment of rates has already been effected. Once in operation and under full load the proposed new plant is expected to show a cost of water delivered to the consumer less than that now borne by the operation of the present plant notwithstanding the fact that the water will be softened and purified.

The nominal capacity of the units to be included in the present construction is set at 24 m.g.d. Under favorable conditions, or in case of necessity, any of the plant elements could be pushed somewhat

beyond this capacity for short periods of time. The forecast of water requirements in Fort Wayne indicate that a capacity of 24 m.g.d. will be reached by the year 1940. Whenever this capacity is reached the system must be enlarged, for which the following provisions are made:

Additional impounding reservoirs will be built on the St. Joseph River above the first reservoir, by which the springtime run-off can be impounded. The water as needed can be passed from the up-river reservoir down the river to the lower reservoir without building pipe lines for this purpose;

An additional supply main can be built alongside the first one from the lower reservoir to the down-town plant;

Additional mixing, coagulation, clarification, settling and filter units can be built in areas provided for that purpose at the down-town station. The pumps first installed may be replaced with larger units as the demand for this equipment increases;

Additional feeder mains may likewise be built as the demand on the distribution system increases.

The construction program has already started. Bids have been received for the construction of the first of the feeder mains and for the filtered water reservoir. It is the plan to have at least a part of the filtered water reservoir in service before the heavy demand of the coming summer. Until the new plant is completed it will be used for the storage of ground water and provision will be made for the installation of temporary pumping equipment to supply the system from this source at those times when the demand for water exceeds the yield of the present supply system.

The program of water works improvements is being carried out under the administration of Mayor William J. Hosey and the Board of Public Works, comprising Mr. J. C. Trier, Chairman, Mr. David Erwin and Mr. Charles A. Ramsey. The engineering plans and specifications for the entire project are in the preparation by Hoad, Decker, Shoecraft and Drury, Consulting Engineers of Ann Arbor, Michigan, from whose preliminary report much of the data and the drawings presented in this paper are drawn. While no construction contracts have yet been awarded it is the intention to employ local labor and materials in so far as practicable upon this work, and it is certain that the undertaking of this project at this time will do much to relieve the unemployment situation in the vicinity of Fort Wayne.

THE TROY WATER WORKS¹

BY JAMES M. CAIRD²

Troy was chartered as a city in 1816, and is located on the easterly bank of the Hudson River at the head of navigation. It occupies the river plain for about six miles north and south, and extends back up the hills eastward from one to two miles. The general elevation of the river plain is about 30 feet, while the hill sections are from 300 to 500 feet above tide water.

It is now about one hundred years since the public water supply was projected, for in the year 1829 a private concern, The Troy Water Works Company, was incorporated.

This Company did little or nothing, so in 1830 the Common Council authorized a committee to investigate and report upon a supply of water for the city. Later in that year a report was submitted suggesting two possible supplies; one at an estimated cost of \$60,000, taking the water from the "Gorton Springs"; the other to use the waters of the "Piscawan" at an estimated cost of \$80,000.

In 1831 attempts were made to negotiate with the Troy Water Works Company, but these failed. In 1832 the city purchased the Company charter for \$174.34; this amount being the actual expenses of the Company to date.

At this time the population was about 12,000, and a house to house canvass was made; the result being that 627 were in favor, 8 opposed and 18 indifferent to the water works project. However, 178 agreed to take water when it was brought to the city.

In 1833 construction of a reservoir on the Piscawankill was started, and contract was let to Samuel Richards of Philadelphia for the cast iron pipe and castings. The prices for the pipe delivered in Troy were as follows:

¹ Presented before the New York Section meeting, April 22, 1931.

² Sanitary Engineer, Troy, N. Y.

DIAMETER, INCHES	PRICE, DOLLARS PER FOOT
12	1.85
10	1.50
8	1.30
6	0.90
4	0.50
3	0.40
Castings	\$62.50 per ton

Some of these pipes are still in service.

The works were completed in 1834 and consisted of a diverting dam across the Piscawankill, two open and one covered reservoirs with a total combined capacity of about one million gallons, and the 12-inch main from the covered reservoir to the city. These reservoirs were east of the Boston and Main Railroad tracks, near Eddy's Lane.

Like the water supply of other growing cities, it was only about two years before it was necessary to consider increasing the supply, for in 1839 "Fire Dam" was constructed upon the site known in later years as the low service distributing reservoir. This reservoir is no longer in use.

This addition also proved insufficient, for during the next year it was suggested that a pumping station be built and a supply obtained from the Hudson River.

The idea of pumping water from the Hudson River did not meet with great favor, and in 1840 a dam was built upon the site of the present Brunswick reservoir.

Between 1859-1868, the full development of the Piscawankill was accomplished by building the "Upper Oakwood," "Lower Oakwood" and "Vanderheyden" reservoirs, which with the "Brunswick" gave a total available storage capacity of about 280 million gallons. These reservoirs have a total drainage area of about 3.6 square miles.

In 1872, owing to a shortage, it was suggested that it would be possible to obtain water from five sources; the Tomhannock, Ploestenskill, Deepkill and Wynantskill Creeks or the Hudson River.

The pumping station to obtain water from the Hudson River was built in 1879 and contained two Holly pumps, each of six million gallon capacity, with the necessary intake and 30-inch force main to the "Lower Oakwood" reservoir, a distance of some three miles.

The "Lower Oakwood" reservoir acted as a settling basin, and the

water flowed to the distributing reservoir which was built in 1883; thence by a 24-inch main to the distribution system.

In 1885 a 24-inch main was laid from the distributing reservoir down Eddy's Lane and Seventh Avenue to Park Street, and connected with the distribution system.

This pumping station was operated to May, 1906, since which time it has been dismantled and converted into a public bath and swimming pool.

In 1879 the middle service system was connected with the "Upper Oakwood" reservoir and a new small reservoir known as the "high Service Distributing Reservoir" was built.

These supplies were adequate until about 1893, when it again became necessary to consider further additions. However, nothing was done until 1900, when authority to expend \$1,250,000 was obtained from the legislature.

In 1901 a start in the development of the Quackenkill drainage area was made by the construction of a diverting dam located near the town line between Grafton and Brunswick and connecting this with the "Brunswick reservoir" some 33,000 feet distant.

The water from the Quackenkill diverting dam enters the Brunswick reservoir through an aerator and flows into the adjacent Vanderheyden reservoir. The combined capacity of these reservoirs is about 210 million gallons, affording time for sedimentation.

In 1913, a 12-inch reinforcing main was laid from Vanderheyden reservoir, and in 1915 another 3,000 feet of 16-inch main was installed.

In 1914 additional storage was developed upon the Quackenkill drainage area by the construction of the "Martin Dunham Dam." This reservoir has a capacity of 600 million gallons, with the flow line at elevation 1,322. The drainage area above this dam is 8.1 square miles and contains six small ponds.

QUALITY OF WATER

Commencing in January, 1925, all water leaving the Vanderheyden reservoir has been treated with liquid chlorine.

The quality of this water is indicated in table 1.

The water is not "hard"; but, owing to the turbidity and color, at times it is not satisfactory in appearance.

The bacterial quality is satisfactory.

In 1929, the "Upper High Service" was created by installing regulating valves and tapping the line between the Quackenkill Diverting Dam and the Brunswick Reservoir.

Strange to relate, this water is "softer" than the water obtained from the Vanderheyden reservoir, although the reservoir receives most of its supply from this source. This would seem to indicate that the water acts upon the soil while in storage.

The hydrogen ion concentration of the water from the "Upper High" service is 6.2; while after passing through the Brunswick and Vanderheyden reservoirs, being in contact with the soil, the hydrogen ion concentration increases to 7.0.

Because of algae growths it is necessary to treat the waters in these reservoirs with copper sulphate.

TABLE 1
Characteristics of water in Vanderheyden Reservoir
Results in parts per million

YEAR	TURBIDITY	COLOR	ALKALINITY	HARDNESS
Average 5 years (1919-23).....	14.5	38.2	23.4	37.5
Average 5 years (1924-28).....	7.2	31.8	23.9	37.9
Average 2 years (1929-30).....	4.2	21.7	20.3	33.8

TABLE 2
Characteristics of Upper High Service water
Results in parts per million

YEAR	TURBIDITY	COLOR	ALKALINITY	HARDNESS
Average 2 years (1929-30).....	2.5	21.7	5.9	22.2

ADDITIONAL SOURCES

When the village of Lansingburgh was annexed to the City of Troy in 1900 they had a water supply which was obtained from three small reservoirs located east of the village. These reservoirs were constructed in 1883 and 1900.

In 1900 there was also under construction a dam on the Deepkill. This dam was resting upon rock and pile foundations, but as serious leaks developed the work was never completed. This drainage area was about 10 square miles.

These supplies are not now in use, and all connections with the distribution system have been removed.

The Tomhannock reservoir furnishes the larger part of the supply for the city, the drainage area being about 67 square miles, and the

capacity 12,310,000 gallons, 95 per cent of which is available. This reservoir has a water surface of 1,685 acres.

Of the area flooded, about 250 acres were covered with woods and brush, which were removed. Seventeen sets of farm buildings and 22,000 cubic yards of muck and decaying vegetable matter were removed from the area to be flooded, but no general stripping was done.

The water from this source was first turned into the city mains on May 21, 1906. The first algae troubles developed under the ice during January, 1908, and since that time it has been necessary to apply copper sulphate to the water at various times.

This reservoir has a maximum depth of 55 and an average depth of 22.5 feet, and is capable of furnishing 38 million gallons of water daily.

TABLE 3
Characteristics of water in Tomhonnock Reservoir
Results in parts per million

YEAR	TURBIDITY	COLOR	ALKALINITY	HARDNESS
Average 5 years (1919-23).....	15.8	25.8	23.8	38.3
Average 5 years (1924-28).....	5.7	22.8	23.3	36.5
Average 2 years (1929-30).....	2.6	15.9	23.6	36.5

During the drought of 1930 this reservoir was depleted 8.5 feet, at which time there still remained available 7.6 billion gallons for consumption. The water was again flowing over the spillway at this reservoir in the early part of April, 1931.

The average consumption from this reservoir is about 21 million gallons per day.

This water was conveyed to the city through a 33-inch riveted steel main, and owing to numerous leaks it was necessary to shut the line off for frequent repairs. In 1914-15 this steel pipe was paralleled by a 30-inch cast iron pipe. At that time this cast iron cost \$19.00 per ton.

Reforestation was started in 1912. At the present time there are about 750,000 trees planted upon the water-shed, and additional trees are being planted at the rate of fifty to seventy-five thousand per year. About 625 acres around the reservoir are now planted with trees.

The quality of this water is indicated by the data in table 3.

These results indicate a "soft" water. It is interesting to note the reduction in turbidity, due to storage; and also the reduction in color, due to storage and the action of light.

The bacterial quality of this water is satisfactory. Since January 1925, liquid chlorine has been applied as the water leaves the reservoir.

The average consumption in the three districts is about as follows:

	<i>gallons per day</i>
Lower Service.....	21,000,000
High Service.....	2,400,000
Upper High Service.....	900,000
Total.....	24,300,000

The 1930 population of Troy is about 73,000, while at least 7,000 in adjacent territory are furnished with water from the city.

There are a total of 274 meters installed in industrial, hotel and mercantile establishments; the total average consumption for these being about 3 m.g.d. or 12.5 percent of the total consumption.

The meter rate is one of the lowest in the state, being only 5 cents per thousand gallons. There is no charge for private fire sprinkler systems, other than the installation.

The total cost of the plant to date is about \$5,100,000, while the present water debt is only about \$1,100,000.

TYPHOID FEVER

In considering the quality of a water supply it is usually customary to study the typhoid fever death rate. The rates since 1900 are shown in table 4.

Considering the typhoid fever death rate in connection with changes in the water supply, it is as follows:

Average for seven years before Tomhannock reservoir was placed in service, 56.4 per 100,000 population.

Average for twelve years with Tomhannock reservoir in service, 24.4 per 100,000 population, or a reduction of 56.74 percent.

The use of the Middle Service was discontinued in 1918, and this service supplied from Tomhannock reservoir. The average typhoid fever death rate was 6.1 per 100,000 population during the next six years, or a further reduction of 25 percent.

Chlorination was installed in 1925, and the average typhoid fever death rate for the next six years was 3.9 per 100,000 population; this being a further reduction of 36 percent.

TABLE 4

Troy, N. Y., and State typhoid fever deaths per 100,000 population

YEAR	TROY	STATE
1900	119.6	26.7
1901	55.9	23.4
1902	53.3	17.4
1903	29.9	21.5
1904	50.7	20.9
1905	50.2	19.2
1906	35.1 Tomhannock, May 21	19.0
Average 7 years.	56.4	21.1
1907	26.0	19.8
1908	35.2	16.0
1909	22.2	15.1
1910	19.5	15.0
1911	24.7	14.0
1912	18.2	11.8
1913	18.1	10.5
1914	34.3	8.9
1915	22.5	7.7
1916	19.9	5.9
1917	29.1	5.7
1918	22.5	5.4
Average 12 years.	24.4 Middle service included in Lower	10.1
1919	5.4	3.3
1920	5.6	3.5
1921	9.8	3.6
1922	9.9	2.9
1923	1.5	2.9
1924	4.4	3.3
Average 6 years.	6.1	3.3
1925	2.8 Chlorination, January	3.5
1926	6.9	2.6
1927	6.9	1.7
1928	1.4	1.7
1929	1.4	1.4
1930	4.1	1.3
Average 6 years.	3.9	2.0

Since the introduction of Tomhannock water and the other improvements, the typhoid fever death rate has decreased 93 percent.

Comparing the State typhoid fever death rate with that of Troy for the same period, there was a reduction of 91.53 percent. However, the Troy rate is slightly higher than that for the entire state.

It is not the intention to convey the idea that the Troy typhoid rate is due to the water supply, as there are various modes of transmission other than by water.

The bacterial quality of the Troy water is satisfactory. Its appearance would be improved by filtration and treatment to reduce the action upon plumbing.

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THE SELECTION AND OPERATION OF CENTRIFUGAL PUMPS¹

BY ROLAND B. HALL AND SAMUEL H. SMITH²

Centrifugal pumping units, particularly electric motor driven, used largely by smaller cities and towns, are unique in that the annual cost of power for their operation nearly always exceeds the first cost of the pump and motor. Frequently, it is two or more times the cost of the pumping equipment.

For example, the power cost of pumping one million gallons of water per day against a head of 200 feet with electric current averaging $1\frac{1}{2}$ cents per kilowatt hour, will be approximately \$5,250.00 per year, and the cost of pump and motor, assuming this to have a capacity of two million gallons daily, will be less than \$2,000.00.

This fact should lead to careful consideration, before purchasing, of characteristics and general suitability of the pump and motor to the service to be performed, in order to accomplish the minimum operating cost. For instance, in the example given, each 1 per cent of combined efficiency of pump and motor is worth \$80.00 per year, or 10 percent on an investment of \$800.00, which sum is more than a third of the entire cost of pump and motor. These figures are not unusual.

NECESSITY OF HIGH INITIAL EFFICIENCY

Electric power is nearly always purchased on a demand charge, plus an energy charge. The demand charge will be found to vary from 25 to 50 percent of the total charge. This portion of the cost is, to a certain extent, within the control of the plant manager, and every effort should be made to keep the demand at a minimum. This may be done by running smaller pumps for longer periods, using the water from elevated storage to carry over the peaks to the maximum extent consistent with safety.

¹Presented before the Southeastern Section meeting, April 8, 1931.

²Of Burford, Hall and Smith, Sales Engineers and Contractors, Atlanta, Ga.

Especially when elevated storage is limited, it is advisable to have several pumps of different capacities, and to operate these in rotation in conformity with the demand curve.

As an example of the mistakes frequently made, a city in this territory using about 2 million gallons of water daily recently bought a 4 million gallon pumping unit. The city happens to have a small elevated storage, and this new unit when used, has to start and stop at 60-minute intervals, or less. Because of the large motor with which it is equipped, the demand charge is increased \$200.00 per month over the previous schedule, when this pump is used. As a result, the pump is of little benefit, except in case of fire, and the city is now considering the installation of another and smaller unit. The only reason for the consideration of the 4 million gallon unit was the desire to obtain plenty of capacity for the future, unfortunately without thought of its effect on the cost of present operation.

There are many thousands of dollars being wasted annually in increased demand charges, because of pump sizes being badly suited to the service performed. We cannot expect that this waste be found and pointed out by the power company's engineers, even though they may be quite willing to assist, but it can be by competent water works engineers and alert plant managers.

MAINTAINING EFFICIENCY

Second only in importance to securing high initial efficiency, is the need of maintaining high efficiency, if pumping costs are to be kept at the proper level.

The electric motor does not change its efficiency materially with age, but unfortunately the centrifugal pump does. From the moment it goes into service its efficiency begins to deteriorate, and sometimes with startling rapidity. Strange to say, there is no outward evidence of this fact.

From the very nature of the design of a centrifugal pump, there must be inside the pump a high pressure or discharge chamber, and a low pressure or suction chamber. These are separated by a running joint, that is, one side of this joint is in motion, and the other side stationary, when the pump is in operation. This means that this joint cannot be a tight fit, and there is always leakage of water from the discharge to the suction. This is the most serious loss of power in a centrifugal pump, and always grows greater as time goes on. If the water pumped is muddy or gritty, this loss increases rapidly, as this

joint wears. However, there is no outward evidence of this, because the pump still continues to give its designed head or pressure.

THE NECESSITY OF MEASURING PUMP OUTPUT

There is only one means of keeping check on this loss, and that is constantly measuring the output of the pump and the input of the electric motor; in other words, constantly checking the efficiency of the unit.

It is an interesting fact that more money is paid out for water that is not measured than perhaps for any other commodity entering into our daily lives. The majority of small towns meter each consumer, but do not meter the total water pumped from their water works plant. Yet, the waste between the two may sometimes be as high as 40 or 50 percent. Not only is a totalizing meter valuable to detect waste and keep down leaks, but it is invaluable in keeping check on the efficiency of pumping and in keeping down pumping costs.

The cost of these meters is small compared with the saving accomplished. For the smaller towns, standard flow meters are accurate and reliable and less expensive than venturi meters. If funds are very limited, a thin plate orifice can be put into the discharge line from the pump for only a few dollars, and a manometer connected across for periodical tests.

As an example of the usefulness of this means of checking capacity and efficiency, a private water company operating in Alabama put in a flow meter in one of their small plants. Out of four centrifugal pumps installed, they found two were so inefficient because of wear, that they could not afford to operate them at all, and yet prior to this, these two pumps were doing their daily stint.

Again, an engineer recently, in buying a small pump, required an overall efficiency guarantee of pump and motor, wire to water. The guarantee of the successful bidder was 66 percent. The plant was small and contained no venturi or flow meter, so he installed a thin plate orifice in the discharge of the pump and tested the pump after installation. The best results obtained were 56 percent, or 10 percent less than the guarantee. As the manufacturer was unable to bring the unit up to guarantee, it was rejected. The annual difference in the cost of power because of this discrepancy in efficiency was \$550.00. In 10 years this town would have paid \$5,500.00 in excess power charges without knowing the difference, but for this engineer's watchfulness.

In another city, it has been found by means of flow meters, that the raw water pumps fall off 8 percent in efficiency in 12 months operation, because of the gritty water. By renewing the sealing rings in these pumps every year, it is possible to save several hundred dollars per year, even though the power cost is less than $\frac{1}{2}$ cent per kilowatt hour. Without the warning of this deterioration given by the totalizing meter, this necessity would not be apparent.

CHECK PUMPS PERIODICALLY

Summing up, our advice to the plant manager is, in the case of existing pumping units, check the overall efficiency of each one of these periodically. If your plant is not equipped with means of measuring the output of each pump, provide such means as soon as possible. You may confidently expect such metering devices to pay for themselves in a short time in the savings accomplished. If your pumps have not been tested for efficiency in a year or more, it will pay you to have careful tests made without delay. These data will determine where repairs and replacements are needed.

With the aid of these metering devices and observation of elevated storage, ascertain your demand for each hour of the day, then plan the operation of your pumps so as to require the minimum power demand and the maximum efficiency in the use of electric energy.

STUDY OF DEMAND CURVES

In the case of new equipment, we would suggest that purchase be made only after a careful study of your demand curve. It is surprising how this information will point toward the most advantageous size for your new pumping unit. We know a small city having a 1,000 and a 2,100 gallon per minute pump, both of which were some years old and were rather badly worn, a fact that was ascertained by efficiency tests being made. A study of the demand curve for water in this city showed that a new pump of a size about half way between these, or approximately 1,500 gallons per minute, would pay for itself in two years by the saving in power, part of this being due to lessened demand charges, and the other to increased efficiency over the old pumps. This city had in mind buying a pump even larger than the 2,100 gallon unit.

ELEMENTS IN PURCHASE

We would suggest also that purchase be made only on guaranteed overall efficiency, that is, both motor and pump, from wire to water, and that the equipment be not fully paid for until this is demonstrated by a test in your own plant. You count your change at the bank, you weigh your groceries and other commodities, and there is no reason why you should take for granted that a contractor or pump manufacturer will give you everything he promises every time. The demonstration is easy; make him prove it.

Another suggestion: the successful and efficient operation of a centrifugal pump is quite dependent on the arrangement and sizes of the pipe connections to the pump, especially the suction connections. Do not buy a centrifugal pump unless the seller will tell you how these piping connections should be arranged, and also assume responsibility for the results with these arranged in this manner. Preferably, have the seller furnish and install the piping with the pump, and then there can be no question about responsibility; he then must turn the pump over to you in successful operation.

There is a considerable amount of engineering involved in the selection and operation of even such simple machinery as centrifugal pumps, if economical results are to be obtained. We are entering a period, everyone agrees, in which all possible waste must be eliminated. Centrifugal pumping machinery, both old and new, will be found a fruitful field for search in this direction.

THE THEORY AND PRACTICE OF AERATION¹

BY WILFRED F. LANGELIER²

Aeration is a unit process employed in the purification of water and in the treatment of sewage. The term, "Aeration," implies the promotion of chemical equilibrium between the gaseous constituents of water and those of the atmosphere. The term is ordinarily used in connection with mechanical devices or procedures specifically intended to increase the surface of contact between water and air, and the designations, "Natural Aeration" and "Reaeration" are commonly used to represent aeration of large bodies of water under natural conditions. "De-aeration" is a term used to denote the mechanical removal of gases in water to concentrations below the equilibrium values at atmospheric pressure. The immediate discussion concerns itself primarily with aeration produced mechanically at atmospheric pressure.

THE PURPOSES OF AERATION

Fresh water, in equilibrium with pure air, contains in solution definite concentrations of the constituents of the air varying only with temperature and pressure. Thus at 20°C. and at sea level, 1 liter of water holds in solution 12.59 cc. of nitrogen (including argon) 6.57 cc. of oxygen and 0.26 cc. of carbon dioxide. Expressed in weight, these values are approximately 15.8, 9.4 and 0.5 p.p.m. respectively. Falling rain approximates this equilibrium composition, but otherwise, water supplies in nature contain varying amounts of these gaseous constituents. Ground waters and bottom waters of lakes and reservoirs are usually deficient in dissolved oxygen and supersaturated with carbon dioxide.

In practice, aeration of water may have for its object either the absorption of oxygen or the removal of carbon dioxide, hydrogen sulphide or other volatile constituents of unknown composition

¹ Presented before the California Section meeting, October 29, 1931.

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resulting from the growth and subsequent decay of plant and animal life inhabiting the water or the soil with which the water has been in contact.

The absorption of oxygen may be desired to promote the oxidation of dissolved iron to render it insoluble or, as in sewage treatment, the absorption of oxygen may be for the promotion of biochemical oxidation of organic matters.

Aeration for the purpose of the removal of carbon dioxide is commonly practised to protect the interior of iron and steel water pipes against corrosion. This is good practice with waters of low alkalinity that have been subjected to treatment with alum for the purpose of coagulation. The alum used in coagulation liberates carbon dioxide and for any given alkalinity, there is a corresponding free carbon dioxide content, which, if exceeded, renders the water capable of dissolving carbonate scale. If the interior of the pipe is not otherwise protected, the removal of the natural carbonate coating may permit corrosion of the iron. It frequently happens, also, that when water of this type is transported through a pipe in which a protective carbonate scale has previously formed, the scale is loosened and detached through the process of partial solution, and the water acquires an objectionable turbidity.

Hydrogen sulphide is frequently a constituent of deep well waters devoid of oxygen. Its presence, in amounts as low as 1 or 2 p.p.m., imparts a characteristic and objectionable odor to water and, if not removed, may permit the development, in the mains, of sulphur bearing organisms, notably *Beggiatoa*. The decay of this organism in water mains may be productive of an odor and taste problem more serious than the presence of hydrogen sulphide alone. Removal of hydrogen sulphide by aeration may be due partly to the escape of the gas into the air and partly to oxidation of the sulphide ion to free sulphur. The latter is not always a complete solution of the problem, because unless the sulphur is removed as by filtration, it may, through the agency of microorganisms in the distributing mains, revert to the sulphide form.

Tastes and odors in water supplies indirectly due to the presence of certain kinds of algae or plankton are of very common occurrence in supplies from lakes and reservoirs. The tastes and odors are usually attributed to highly volatile oils secreted by the living organisms. After death, the characteristic odors may be replaced by odors of decomposition. As a preliminary step in the purification of such

waters, aeration is usually somewhat beneficial and is commonly practised.

Aeration of water is sometimes resorted to for no other reason than to enhance the attractiveness of a reservoir or water works plant. This is a reasonable use, often justifying its cost. The most important use of aeration, however, is in connection with the treatment of sewage.

THEORY OF AERATION

The volume of air, or its constituent gases which will dissolve in water, is independent of pressure, but since the weight of gas in a given volume increases in direct proportion to its pressure, it follows that the weight of air dissolved must also vary directly with pressure. This is in accordance with the well-known Henry's law, which also applies to partial pressures. Thus, since air contains 21 percent of oxygen by volume, water in contact with air will dissolve only 21 percent of the volume it would dissolve were it in contact with the pure gas under the same total pressure. Also, since the partial pressure of hydrogen sulphide in normal air is zero, water in equilibrium with the atmosphere may contain none of the gas.

Of the three principal gases of the atmosphere carbon dioxide is the most soluble. In contact with the pure gas, one volume of water at 18°C. will dissolve approximately one volume of the gas. The partial pressure of carbon dioxide in the air, however, is very low, only three hundredths of 1 percent; therefore, water in equilibrium with air contains only three ten thousandths of its own volume, or about 0.5 p.p.m. by weight.

The rate of solution of gases in liquids has been extensively studied. The earliest work was done in connection with certain chemical processes. Gay Lussac in 1827 proposed the use of a scrubbing tower for the recovery of nitrogen compounds in the manufacture of sulphuric acid. The work of Phelps (1) on the mechanism of air absorption, and the relation of air absorption to the pollution of New York Harbor published in a series of papers dating from 1911, is especially noteworthy. A continuation of this work in collaboration with Streeter (2) in its application to problems of river pollution was published in 1925. During the years 1918 to 1926, Adeney and co-workers (3) have reported the results of extensive laboratory studies of aeration phenomena, and it is principally the work of these authors which is used as a basis for discussion in the present paper.

One method of experimentation employed by Adeney and Becker consisted of enclosing a large bubble of air or gas of known volume in a tube containing de-aerated water, also of known volume, and of allowing the bubble to ascend through the water column repeatedly, until saturation was reached. The pressure of the bubble was measured after each double passage up the tube by means of a manometer, after which observation the air in the bubble was removed. The observed pressure readings enabled calculation of the absorption which took place step by step to saturation.

Repetition of this experiment with various bubble sizes and temperatures showed that the absorption of gas under these conditions could be equated into terms dependent on bubble area and volume, the gas pressure and the concentration of the dissolved gas. The results were found to be in agreement with the general formula:

$$W = (w_s - w_i) \left[1 - e^{-0.01 (T+36) \frac{A}{V} t} \right]$$

in which W = increase in concentration of gas at end of (t) minutes, w_s = concentration of gas at saturation, temperature $T^\circ\text{C.}$, w_i = initial concentration of gas, e = base of common log = 2.718, A = area of contact surface in square centimeters, V = volume of water in cubic centimeters.

This equation in effect states that for any given aerator installation, there is a constant, which we may call the aerator constant for that installation. It is numerically less than one and is equal to the term enclosed within the large bracket. If this constant is multiplied by the saturation deficit ($w_s - w_i$), we obtain the proportion of the deficit which will be absorbed. If desired, the concentrations may be expressed in terms of percentage saturation in which case (w_s) becomes 100.

The authors propose this equation, with the exponential constant as given, only for the absorption of oxygen, nitrogen and air, in contact with fresh water under the experimental conditions used.

These authors did not investigate the removal of a saturation surplus, but other investigators (4) have shown that the theory of gas removal by aeration is identical with that for absorption and that the aerator constant should hold for any of the moderately soluble gases of the atmosphere in pure water. In this case ($w_s - w_i$) represents a saturation surplus and will have a negative sign.

In table 1 the solution is given of the Adeney oxygen absorption equation for various conditions of time and temperature while the ratio of A/V remains constant and equal to 20. This value of A/V is that which obtains when one volume of water is aerated with one volume of air divided into bubbles of 0.3 cm. diameter. If the equation were valid for surface or stream flow aeration without a correction factor, the values given would be for the saturation of a surface film 0.05 cm. thick.

At the Massachusetts Institute of Technology, Lewis and Whitman (5) and co-workers have shown that in the absorption of a moderately soluble gas such as oxygen, the rate of absorption is controlled by the thickness of a stationary water film at the interface, whereas in the

TABLE 1

SATURATION PERCENT	TEMPERATURE, °C.						
	0	5	10	15	20	25	30
	Time in seconds						
10	1.0	0.8	0.8	0.7	0.7	0.6	0.5
20	2.1	1.8	1.6	1.4	1.3	1.3	1.2
30	3.2	2.7	2.3	2.0	1.8	1.7	1.6
40	4.5	4.0	3.6	3.3	2.9	2.7	2.4
50	6.0	5.2	4.6	4.2	3.9	3.6	3.3
60	8.0	7.2	6.4	5.7	5.0	4.6	4.3
70	10.5	9.3	8.2	7.3	6.7	6.1	5.8
80	14.0	12.5	11.0	10.0	9.0	8.3	7.7
90	19.8	17.5	15.6	14.2	13.0	11.9	10.8
99	39.6	35.0	31.2	28.4	26.0	23.8	21.6

absorption of a very soluble gas, the thickness of the water film is immaterial and the rate of absorption is dependent upon the thickness of the gas film on the opposite side of the interface. They conclude that bubble type of aeration should be more efficient than waterfall type, because in the former case a gas bubble rising through the water would continuously expose a fresh liquid surface with a thin stationary film; whereas, in waterfall aeration a falling drop might be expected to have a thin air film but a thick water film. If this reasoning is correct, the absorption equation of Adeney should give high results if applied to aerators not of the diffusion or bubble type. A minimum rate of absorption would occur under those conditions where the exposed water surface offers a minimum of

turbulence. Tests of air absorption through both quiet and moving water surfaces, with results compared to bubble aeration computed to the same values of contact surface and time, should be of interest. Here again, the work of Adeney is illuminating.

In one experiment, perfectly quiescent, deaerated water exposed to moist air was found to absorb air two-hundred-and-fifty-fold slower than indicated by the general equation. The same experiment, using dry air, showed an absorption only 50 times slower than the equation rate. The explanation of this five-fold increase in the rate of absorption is that, in the exposure to dry air, sufficient evaporation occurs to cool the surface film, thereby inducing vertical circulation of the instantly saturated surface film. When sea water was used, an even greater rate of absorption was noted. In this case, circulation is assisted by the increased density of the more concentrated solution forming at the surface. Most remarkable, however, was the fact that when a column of water 4 feet deep was agitated at the surface to simulate wave action, the rate of absorption was found to be only four-fold slower than indicated by the absorption equation.

These carefully controlled experiments show very clearly the importance of constant renewal of the surface water film, and furnish a basis for estimating the relative efficiencies of various types of aerating mechanisms.

Another matter of importance in the consideration of aeration theory concerns the rate of oxygen absorption in water which contains an excess of deoxygenating material, as, for example, activated sludge. Here we are interested primarily in the initial rates for deaerated water. The work of Becker (6) shows that the initial rate is constant for the various temperatures experimented with and, for bubble aeration, was equal to 0.204 cc. of oxygen absorbed per square centimeter of interface per hour. In surface aeration experiments, wherein water containing an excess of ferrous hydroxide was swirled at a very high angular velocity (1000 r.p.m.), the rate was one-half and for a low velocity (80 r.p.m.) the rate was one-eighth of the initial rate for bubble aeration.

THEORY IN RELATION TO PRACTICE

In practice, aerator installations for water purification purposes are most often predicated upon existing conditions of available head and space. Thus in the case of an impounded gravity supply,

sufficient head for aeration is usually available without pumping. If the head fluctuates seasonally within wide limits, it is desirable to select a unit which will function over a wide range of head, as, for example, certain types of nozzle aerators. In other instances, as for example, an aerator located between filters and clear water storage basins, for the purpose of decarbonation, may have available only 3 or 4 feet of head. In this case, a constant and low head unit is essential. Occasionally an aeration unit is desired as an addition to existing water treatment structures where neither head nor space for a waterfall type of unit is available. In such cases, an air diffuser unit located in an existing storage reservoir may be used.

Consideration of the theory just described discloses that there are five factors which determine the effectiveness of an aerator installation, whether used for the absorption of oxygen or for the removal of carbon dioxide or other volatile substances. These are: (1) temperature of the water, (2) saturation deficit (or surplus) of the gas in the water, (3) area of contact surface per unit volume of water, (4) time of contact, (5) turbulence of water at contact surface.

Temperature and saturation

Reference to table 1 shows that, in order to secure the same effect as measured in terms of percentage saturation, only one-half as much time of contact is necessary at 30°C. as is required at 0°C. From this, it would appear that an aerator installation is more effective in summer than in winter. Actually, the weight of gas absorbed is greater at the lower temperature. Note that at 30°C., the time required to attain 99 percent saturation yields 91 percent at zero. The oxygen values are 7.6 and 13.8 p.p.m. respectively.

It has been noted that the effectiveness of aeration, as measured by the weight of gas absorbed or removed, is greater the further the initial concentration of the gas is removed from its equilibrium or saturation value. This fact should be considered in the determination of the relative economy between aeration and neutralization with lime for the removal of free carbon dioxide from water. In the latter process, the lime requirement varies directly with the weight of carbon dioxide to be removed and relatively, therefore, is most efficient when the concentration of the gas is low.

In the matter of tastes and odors, however, it should be borne in mind that they may not always increase in direct proportion with the concentration of the substances which cause them and that it is

entirely possible that a 50 percent removal of some odoriferous substance might affect the taste and odor not at all, or again, it might completely remove them.

Contact surface and time

Whereas temperature and initial concentration are not subject to control, the important factors of contact surface and time are dependent upon design or type of installation. As between any two aerators of the same type to treat the same water, performance will depend largely on the product of contact surface and time. Although this fact is too obvious to warrant much discussion, it would appear that the significance of the reciprocal relationship of surface and time in the practice of aeration has not been always fully appreciated. Example, water stored in an open basin for a few hours may undergo a degree of aeration comparable to that which would obtain if the water had been treated in a specially built aerator. The effective exposure $\left(\frac{A}{V} \times t\right)$ of water stored in an open basin 10 feet

deep for a period of five hours, is equivalent to that of drops of 1 cm. diameter falling through a head of 15 feet. If allowance is made for a greater degree of turbulence at the contact surface of the falling drops by doubling the time requirement of storage in the basin aeration, we still must conclude that in the passage of water through a typical water purification plant comprising coagulation, sedimentation, filter and storage basins, a considerable degree of "natural" aeration will take place. Between these two extremes of aerating devices, the one utilizing primarily head and the other storage, there is a multiplicity of practical procedures employing the principles of (1) the free fall; (2) cascades; (3) the inclined plane with riffle plates; (4) stream flow. Compared to the free fall, cascades and the inclined plane as commonly used are efficient compromises wherein contact surface may be partially sacrificed in favor of an increase in the time element.

Waterfall versus diffusion aerators

In the choice between waterfall and diffusion types of aerator units, as used in water purification, practice favors the former, but theory strongly favors the latter. A diffusion unit wherein finely divided air bubbles are introduced over the bottom of a basin through which water is flowing, provides most adequately for practically all

of the factors that control the efficiency of aeration. This appears to be the unanimous conclusion of all the investigators that have pioneered in the research of air absorption problems. Perhaps the principal advantage arises from the fact that the velocity of bubbles ascending through water is several-fold lower than the velocity of free falling drops of water, thus affording a longer period of contact for an equal expenditure of energy.

The laws of rising gas bubbles through water are rather complicated, but approximate measurements indicate a mean velocity of something less than 1 foot per second. It has been shown, moreover, that acceleration is practically nil and on account of the induced turbulence the velocity within limits is independent of the size of the bubbles. The effect of increased time which is available with the diffusion method of aeration as compared with the free falling drop method and the comparative energy requirements of each method is of interest.

Assume one volume of water aerated with one volume of air subdivided into bubbles of radius (r) in a basin of depth (H) by the diffusion method. Assume also that in the falling drop method, one volume of water is subdivided into drops of the same radius (r) and allowed to drop through the same height of (H).

The energy requirements for the two methods will be the same and equal to $(V \times H \times 62.5)$ foot pounds.

The ratio of the effective contact $\left(\frac{A}{V} \times t\right)$ of the bubble method to the drop method will be found to be $\frac{1}{2} \sqrt{2gH}$. Thus, in a basin where the depth of water to the diffuser is 16 feet, the product of interface and time is 16 times greater than in the falling drop method. Reference to table 1 shows that for the value of A/V as given this difference would account for an absorption of about 15 percent for the drop method, as compared to 90 percent for the bubble method, if we assume the applicability of the Adeney equation to waterfall aeration.

The fact that bubble type of aeration is not more frequently used in water purification in spite of its apparently greater efficiency is due to a number of causes, some of which have already been mentioned. Waterfall aeration may often utilize existing pumping facilities or in many instances the head is available without additional pumping. Also, sprays and cascades are attractive to the eye, and possess a distinct architectural value.

Nozzles and cascades

It has been pointed out that cascades increase the time of contact by reducing the acceleration due to gravity of a free falling body. On the other hand, certain types of nozzle aerators provide a certain degree of contact during the rise of the water as well as during its descent. Other types of nozzles, as for example, the Sacramento type, throw the water out in a thin film at an angle with the vertical. Among the various types of nozzles available for aeration of water, there is a wide divergence in the degree of contact surface afforded. The fact that one nozzle operates under a higher head than another does not imply that it is more efficient. Some nozzles are designed for high capacity and limited space; others sacrifice capacity and space for efficiency of contact. In general, aerator nozzles of various types require heads from 5 to 20 feet for their successful operation.

CIRCULAR FLOW BUBBLE AERATION IN THE ACTIVATED SLUDGE PROCESS

Aeration by air diffuser units is used extensively in the activated sludge process of sewage treatment. It is a common opinion that in this case the air serves at least two purposes; first, to supply oxygen for biochemical oxidation, and second, to induce a movement of the water which promotes coagulation and clarification. It is barely possible, also, that the air serves to rid the sewage of objectionable by-products of the oxidation, as for example carbon dioxide, the presence of which would lower the pH value. This is merely speculation and not pertinent to the present discussion. The writer is now conducting experiments to determine if the two first-mentioned functions of air dosage could not be served more properly by two separate mechanisms, namely, a unit to provide suitable air diffusion and a separate unit to provide uniform circular motion, as developed by the writer (7) for the coagulation of water.

In such a process, the air bubbles should be small. It has been shown by Maier (7) that a bubble released from a submerged orifice by buoyant effects only, attains a size of approximately ten times the orifice diameter. The orifice spacing should be ten diameters in order to prevent coalescence. The commonly used porous plate diffuser does not meet this specification. On the other hand, small orifices would probably tend to clog rapidly and there is need of an air diffuser which employs the principle of a shearing force to release the bubbles before they have attained their normal static size. The

writer has demonstrated by laboratory experiment that a circular motion of the sewage as proposed will accomplish this purpose for at least a portion of the bubbles liberated and, at the same time, the smaller bubbles will be given a greater distance of travel as they circle upward through the tank before reaching the surface.

CONCLUSION

A review of the periodical literature of the past decade on the treatment of public water supplies contains references of some fifty or sixty aerator installations. Approximately four-fifths of these installations are of the water-in-air type. Approximately one-half of these are spray aerators employing various types of nozzles. It appears, further, that approximately one-half of all aerator installations are for the purpose of removing tastes and odors, and the remainder for the removal of carbon dioxide or the removal of iron. Much of the data reported, however, are fragmentary, and a critical examination of the performance data indicates that reported results are conflicting and not altogether reliable.

In general, perhaps it may be said that aeration is most successful in the treatment of well waters devoid of oxygen, as a preliminary treatment in the removal of iron. In obstinate cases of taste and odor removal, aeration is only partly successful. In this connection, it is probable that more intensive aeration than is now practised is desirable. The apparent advantages of the air diffusion method combined with mechanical stirring as practised in the coagulation of water do not seem to have been fully realized in the practice of sewage aeration.

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THE EFFECT OF THE 1930 DROUGHT ON THE WASHINGTON WATER SUPPLY

BY CARL J. LAUTER¹

The water supply of Washington, D. C., taken from the Potomac River at Great Falls, 10 miles above the District of Columbia line, has never suffered such a marked change in character as was experienced during the last six months of 1930, which is the period under discussion in this paper. The deficiency in rainfall began to manifest itself as early as January, 1930, and by June 30, there were 6.8 inches less than normal, and by December 31, we had a total deficiency of 20.5 inches for the year, or 13.7 inches in the last six months. During this period, the normal rainfall is 20.5 inches. This, therefore, gave us only a 33 percent normal rainfall for the six-month period under consideration.

During this time the stream flow of the Potomac River, measured at Great Falls, fell from around 2,700 to 500 second-feet in August, 1930, the date of lowest discharge, but, with the prolonged drought throughout September, October and November, the ground water elevation continually dropped and the effect of spring waters became more apparent. That is, the proportion of spring waters to ground water became greater and the calcium content became greater and greater with a maximum in December.

The two instances of rain in September and early December had only a temporary effect on the general character of the water, and not until the December 25 rain did we experience any great change for the better.

From the accompanying data of diminished rainfall and stream flow it is evident that some change in the composition of the water must naturally follow, especially when we consider that about November the surface flow practically ceased and the river took on the character of a limestone spring water, with a greatly increased hardness and alkalinity, which kept going up and up until the latter

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part of December, 1930, at that time the total hardness was 130 parts per million as calcium carbonate and the pH 8.2, with a methyl orange alkalinity of 120.

While 7.5 grains are not considered extremely bad in some localities it is abnormally hard in this region where the average hardness for this period is generally less than 3.5 grains. With the high alkalinity and the presence of normal carbonates, the water was scale forming to a high degree, since most of the hardness was present as bicarbonates and precipitated CaCO_3 upon heating.

The water from the rapid sand filters was better than that from the McMillan slow sand plant in this respect, as we maintained some CO_2 in the effluent from the former, whereas the latter was untreated and contained normal carbonates practically in the same amounts as in the raw waters.

There was little or no change in the silica, iron, aluminium and chloride content over the average of past years, and although the stage was low, the bacterial content was low, due of course, to the purifying nature of the mountainous stream and freedom of gross pollution of sewage wastes near the inlet conduits.

There were some pollution effects, however, which will be discussed later. Accompanying these chemical and bacteriological data, it may be interesting to mention that the turbidity for this entire period was exceedingly low. The average turbidity for the six months was about ten, or about 5 parts per million of suspended matter, with a maximum turbidity of twenty-five, or 13 parts per million of suspended matter.

This turbidity coupled with the high alkalinity and pH, required a higher alum dosage than normally, to give a water suitable for the filters. At no time could we go below one grain per gallon and then only with sulphuric acid added, to bring down the pH and alkalinity to an optimum point for floc formation.

On account of these and other operating conditions, our filter runs began to drop around the first of August to about twenty hours. At this time, we began to add mud to the water entering the plant in amounts necessary to create a turbidity of about twenty or thirty. This was done by stirring clay in a mortar box with a continuous stream from a hose, allowing the heavy mud to run out of the box into the conduit, entering the plant. There was some noticeable effect, inasmuch as the filter runs showed about 10 to 20 percent longer periods between wash, which fact was checked by

alternately stopping and starting up the mud, with intervals of two and three days, when no mud was added. A good deal of this mud was naturally deposited in the settling basin as it was impossible to get it in the same state of fine subdivision as is naturally present, but we think the experiment was a success for the period.

At this date a great excess of sulphuric acid was added to the alum solution which treatment was again followed by a very good rise in filter runs, jumping from 9 to 42 hours in one day's time. The amount of acid fed varied from one to two grains per gallon of 60° Be. H_2SO_4 , with an alum dosage of 1.5 grains. The general effect was a decided improvement and carried us through the period of clear, hard water until conditions were again more improved by rains and muddy waters.

Along with these operating difficulties we received complaints from consumers on the hardness of the water and clogged heater coils on hot water heaters, all evidence of the fact that we were experiencing abnormal conditions.

Perhaps the worst effect of the drought did not reach us until after it was broken and heavy rainfall of the latter part of December began to bring down the deposits accumulated on the water-shed during the dry month. About January first or second we had a taste developed in the water which was rather pronounced, imparting a woody-like or naphtha odor. It came in very suddenly and lasted only three or four days at the plant, although its effects were noticeable in the city supply for a longer period. Ammonia treatment was tried with chlorination, but the trouble stopped before a good test could be made.

About two weeks later a second taste spell came through which again lasted only three or four days. This outbreak came about four or five days after a similar outbreak at the Hagerstown filter plant located at Williamsport, Maryland, the only other filter plant taking water for drinking from the Potomac River below Cumberland.

At this time phenols were found in the Hagerstown supply to the extent of 80 to 140 parts per billion and ammonia and chlorine were tried there without much relief, according to information given me by Mr. Cannen, the Chemist-in-Charge.

On February 9, we had a third outbreak following which I made an inspection trip to Greenspring, W. Va., where the B. & O. railroad operates a large creosote tie-treatment plant. I had seen this plant in the spring of 1930 and the superintendent of the plant admitted

that they were losing perhaps five gallons of heavy creosote oil daily. The river bottom had pools of this heavy, tarry mixture and the rocks were all stained with oil at the points where drainage from the plant entered the stream.

On February 16, 1931, there was a larger water flow in the river and not such a great evidence of standing pools of creosote oil. Samples of water taken below this plant gave strong phenolic reactions with only a little evidence of the same, above the plant, indicating another source of contamination somewhere above this point, probably above Cumberland.

A sample of water taken at the Keyser bridge May, 1930, at Keyser, W. Va., showed a very strong phenol content, perhaps 200 parts per billion. Samples taken above the paper mill at Luke at this date and again later, were entirely free, while just below the paper mill the samples were extremely high on this early date and on April 2, 1931, at this time the Keyser figure was much lower, due to a much higher stream flow and the odor in the river was also less pronounced.

About February 20, we had our last taste spell in Washington, following a similar one at Hagerstown on February 15. The ammonia treatment with chlorine, prior to filtration, and raising the pH with lime in the effluent of the plant seemed to help conditions. We had only one or two complaints. Tastes were not so noticeable in the city, although tests for phenol in the city supply were positive, perhaps 10 to 15 parts per billion.

Since then we have improved our method for ammonia application by placing it in the settled water conduit coming to the filters, prior to the point of pre-chlorination in the same flume, but we have had no occasion to try it out as heavy rains have diluted the river to a point where we find no phenol in the raw water, and we have no other taste trouble to report.

From the occurrence and recurrence of these tastes after these successive rains it is evident that the heavy creosote matter must have collected in the sluggish stream of last fall and was washed down in the heavy flows following the rains and will doubtless be a source of future troubles unless better means of waste treatment are provided.

Since March, with better stream flow and occasional heavy turbidities, we have had improvement in all operating conditions. The filter runs again rose to better than 72 hours and a one grain alum dosage on 30 turbidity water is often sufficient to perform the work properly.

Springs and wells in the vicinity of Washington also suffered, and during October, November and December our water service was extended to the Washington Suburban Sanitary District, which furnishes water to Hyattsville and other Maryland points.

At no time, however, was the supply of the District of Columbia endangered, although the Great Falls of the Potomac could scarcely

TABLE 1

Rainfall in the District of Columbia during 1930 and normal average rainfall, inches

MONTH	1930	NORMAL
January.....	2.85	3.55
February.....	1.64	3.27
March.....	2.26	3.75
April.....	3.12	3.27
May.....	1.81	3.70
June.....	3.19	4.13
First 6 months.....	14.87	21.67
Shortage.....	6.80	
July.....	2.30	4.71
August.....	0.62	4.01
September.....	0.76	3.24
October.....	0.28	2.84
November.....	0.79	2.34
December.....	2.04	3.32
Last 6 months.....	6.79	20.46
Shortage.....	13.67	
Total.....	21.66	42.13
Shortage.....	20.47	

live up to its name. At the time of diminished flow the stream flow was 754 second-feet at the falls, of which we used 316 second-feet for water supply and hydro-electric power. Of this figure we used about one-half for power and one half for filtration purposes.

Ultimately the construction of a system of retaining reservoirs should alleviate any possibility of a shortage when the demand comes near this point.

MANGANESE BACTERIA IN THE WATERS OF TEXAS

By F. W. JESSEN¹

The waters of Texas vary considerably in salt content. The waters of West Texas, generally from deep subterranean sources, are quite hard, while those of East Texas, generally from sources not so deep, are rather soft. The presence of compounds of such elements as manganese, iron, and other metals makes it more difficult to treat such waters in order to make them potable. Industrial processes quite frequently demand a water free from any such compounds. Probably the greatest trouble attributed to manganese in waters is that of blackening and caking of filter beds (1), and aftergrowth in pipe lines (2, 3).

Previous investigators have shown that manganese is deposited on filter beds supposedly in the form of the black dioxide. However, Kuhr (1) seems to have been one of the first to study the form of the deposit and the actual organisms involved in the deposition process.

The purpose of this investigation was to determine the manganese content of as many waters of the state as possible, and also to isolate from these waters, if possible, organisms which were capable of oxidizing manganese. The distribution of these organisms, and the correlation existing between their presence in the waters and the presence of manganese, were also to be studied.

METHODS OF INVESTIGATION

Many of the waters examined were collected by the writer; but most were supplied by the county health officers of the State. The Bureau of Industrial Chemistry also supplied quite a number of the samples. Water was collected from approximately 130 counties from all parts of the State, of either surface, spring, or well origin. A total of 150 samples was examined for manganese content.

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TABLE 1
Manganese content of Texas waters

NUMBER	COUNTY	SOURCE OF WATER	MANGANESE	
			P.p.m.	Bacteria
1	Anderson (1)	Spring	0	None
2	Anderson (2)	Spring (purified)	0	None
3	Bailey	Well (shallow)	0	None
4	Bastrop	Well (shallow)	2.2	None
5	Bell	Well (shallow)	0	None
6	Bexar (1)	Well (147 ft.)	0.11	None
7	Bexar (2)	Well (92 ft.)	0.02	None
8	Blanco	Well (shallow)	0	None
9	Bosque	Spring	0	None
10	Brewster (1)	Well (250 ft.)	0.02	None
11	Brewster (2)	Well (6 ft.)	0	None
12	Briscoe	Well	0	None
13	Burleson (1)	Spring	0	None
14	Burleson (2)	Spring	0	None
15	Burleson (3)	Surface (creek)	0	None
16	Burleson (4)	Well (shallow)	2.60	None
17	Caldwell	Spring	0	None
18	Calhoun	Well (30 ft.)	0	None
19	Callahan	Well	0	None
20	Cameron	Surface	0	None
21	Cass	Well	0	None
22	Cherokee (1)	Well (surface)	0	None
23	Cherokee (2)	Well (surface)	0	Present
24	Cherokee (3)	Well (surface)	0	Present
25	Cherokee (4)	Well (surface)	0	None
26	Cherokee (5)	Spring	0	None
27	Cherokee (6)	Spring	0	None
28	Childress	Surface	0	None
29	Coke (1)	Surface	0	None
30	Coke (2)	Surface	0	None
31	Cottle	Well (100 ft.)	0	None
32	Culberson	Well (600 ft.)	0	None
33	Deaf Smith	Well (shallow)	0	None
34	Denton	Spring	0.42	None
35	Fannin	Well (deep)	0	None
36	Fayette	Well (shallow)	0	None
37	Fisher	Surface	0	None
38	Floyd	Well	0	None
39	Foard	Surface (lake)	0	None
40	Fort Bend	Well	0	None
41	Frio	Well	0	None

TABLE 1—Continued

NUMBER	COUNTY	SOURCE OF WATER	MANGANESE	
			P.p.m.	Bacteria
42	Galveston (1)	Surface	0	None
43	Galveston (2)	Surface	0	Present
44	Galveston (3)	Surface	0	Present
45	Galveston (4)	Surface	0	Present
46	Garza	Well (deep)	0	None
47	Gonzales	Surface (Guard. R.)	0	None
48	Grayson (1)	Well (artesian)	0	None
49	Grayson (2)	Well (shallow)	0	None
50	Hansford	Well (400 ft.)	0	None
51	Hardeman	Well (shallow)	0	None
52	Harris	Well (700 ft.)	0	None
53	Hartley	Well (deep)	0	None
54	Haskell	Well (20 ft.)	0	None
55	Hemphill	Surface	0	None
56	Hill	Well (shallow)	0	None
57	Hockley	Well	0	None
58	Howard (1)	Well (6 ft.)	0	None
59	Howard (2)	Well (14 ft.)	1.21	None
60	Howard (3)	Well (40 ft.)	0	None
61	Hudspeth	Well (800 ft.)	0	None
62	Irion (1)	Spring	0	None
63	Irion (2)	Well (250 ft.)	0	None
64	Jack	Well	0	None
65	Jim Hogg	Well (shallow)	0	None
66	Karnes	Well	0	None
67	Kendall	Well	0	None
68	Kent	Well	0	None
69	Kimble	Spring	0	None
70	La Salle	Well (2300 ft.)	0	None
71	Lamar	Surface	0	None
72	Lee (1)	Well (shallow)	0.7	None
73	Lee (2)	Well (shallow)	0	None
74	Lee (3)	Spring	2.1	None
75	Lee (4)	Well (shallow)	1.3	None
76	Limestone	Well (157 ft.)	0	None
77	Live Oak	Well	0	None
78	Lubbock	Well (140 ft.)	0	None
79	Lynn	Well (shallow)	0	None
80	McLennan	Well (shallow)	0	None
81	McCulloch	Surface	0	None
82	Mason	Well (artesian 800 ft.)	0	None
83	Matagorda (1)	Well (artesian)	0	None
84	Matagorda (2)	Well (shallow)	0	None

TABLE 1—Continued

NUMBER	COUNTY	SOURCE OF WATER	MANGANESE	
			P.p.m.	Bacteria
85	Medina	Well (85 ft.)	0	None
86	Midland	Well (deep)	0	None
87	Milam (1)	Well (shallow)	0	Present
88	Milam (2)	Well (mineral)	0	None
89	Milam (3)	Surface	1.0	None
90	Milam (4)	Spring	3.6	None
91	Milam (5)	Well (25 ft.)	0	None
92	Mitchell (1)	Well	0	None
93	Mitchell (2)	Spring	0	None
94	Montague	Well	0	None
95	Moore	Well	0	None
96	Morris	Well	0	None
97	Nacogdoches	Well (750 ft.)	0	None
98	Nolan	Surface and well	0	None
99	Panola	Well	0	None
100	Parker	Well (deep)	0	None
101	Parmer	Well	0	None
102	Potter	Well	0	None
103	Red River	Spring	0	None
104	Reeves (1)	Spring	0	None
105	Reeves (2)	Surface (Pecos R.)	0	None
106	Reeves (3)	Well (80 ft.)	0	None
107	Reeves (4)	Well	0	None
108	Refugio (1)	Well (960 ft.)	0	None
109	Refugio (2)	Well (shallow)	0	None
110	Roberts	Well (deep)	0	None
111	Rusk	Well (30 ft.)	0	None
112	San Saba	Well (shallow)	0	None
113	Starr (1)	Surface (Rio Gr. R.)	0.8	None
114	Starr (2)	Well	0	None
115	Starr (3)	Surface (filtered)	0	None
116	Travis (1)	Surface (Colo. R.)	0	None
117	Travis (2)	Well (30 ft.)	0	None
118	Travis (3)	Spring	0	None
119	Travis (4)	Surface	0	None
120	Travis (5)	36 ft. well (E. of Austin)	0.1	None
121	Travis (6)	Well (capitol 1200 ft.)	0	None
122	Travis (7)	Surface	0	None
123	Terrell	Well	0	None
124	Tom Green	Well (65 ft.)	0	None
125	Uvalde	Well (85 ft.)	0	None
126	Val Verde	Springs	0.02	None
127	Van Zandt (1)	Wells (25 ft.)	0	None

TABLE 1—*Concluded*

NUMBER	COUNTY	SOURCE OF WATER	MANGANESE	
			P.p.m.	Bacteria
128	Van Zandt (2)	Wells (20 ft.)	0	None
129	Ward (1)	Wells (shallow)	0	None
130	Ward (2)	Surface (Pecos R.)	0	None
131	Washington	Well (shallow)	0	None
132	Wharton	Well (deep)	0	None
133	Willacy	Well (deep)	0	None
134	Williamson	Well (shallow)	0	None
135	Wilson	Well	0	None
136	Young	Well	0	None
137	Zavalla	Well (500 ft.)	0	None

Chemical analysis

The manganese was determined initially by two methods in order to insure correct results. The *periodate* method of Willard and Greathouse (4), and the *sodium bismuthate* method of Collins and Foster (5) were used. Both methods gave consistent and comparable results. Because of the ease of manipulation, however, subsequent analyses were made by the latter method. The bismuthate method gave a color which could easily be compared with the permanganate solution used as a color standard.

Bacteriological methods

In the bacteriological procedure standard methods were used. The synthetic manganese agar used was prepared with Baker's C.P. chemicals. The method of isolation of the organisms was that of Kuhr (1), who used a medium of the following composition:

Dune water.....	100	cc.	
Agar.....	2.5	gm.	
Ca(CH ₃ COO) ₂	1.0	gm.	
(NH ₄) ₂ SO ₄	0.1	gm.	pH = 8.1
K ₂ HPO ₄	0.05	gm.	
MnCO ₃	1.0	gm.	

The pH of the medium used, however, was adjusted to 7-7.2 with bromthymol blue, since Kuhr (1) found that the organisms that oxidized manganese to the dioxide could be cultivated on a medium having a pH as low as 5.

After inoculation on this "manganese agar" medium, the plates were incubated for about three weeks at room temperature. At the end of this time, small round black or brown colonies appeared on the plates. These were "fished" to nutrient agar plates, pure cultures obtained, and these re-inoculated on the "manganese agar" used above. The growth on the manganese agar was markedly

TABLE 2
Numbers of organisms

NUMBER		SOURCES OF WATER FROM WHICH ISOLATED
1	Galveston Co. 2 Black (1)	Creek water, Galveston County
2	Galveston Co. 3 Black (1)	Dickenson Bayou, Galveston Co.
3	Galveston Co. 2 Black (2)	Creek water, Galveston Co.
4	Galveston Co. 3 Brown (1)	Dickenson Bayou, Galveston Co.
5	Galveston Co. 3 Brown (2)	Dickenson Bayou, Galveston Co.
6	Galveston Co. 4 Brown (1)	Surface water, lagoon, Galveston Co.
7	Galveston Co. 4 Brown (2)	Surface water, lagoon, Galveston Co.
8	Cherokee 2. B-B ₁	Surface well, Cherokee Co.
9	Cherokee 2. Black (1)	Surface well, Cherokee Co.
10	Cherokee 2. B-B ₂	Surface well, Cherokee Co.
11	Galveston Co. 4 B-B	Surface water, lagoon, Galveston Co.
12	Cherokee 3 Black (2)	Surface well, Cherokee Co.
13	Cherokee 3 Brown	Surface well, Cherokee Co.
14	3187. Black	Spring and Surface, Milam Co.

The above table gives the index numbers of the organisms, used merely for simplifying the routine of transplanting, etc. The numbers in parentheses indicate the number of colonies on the manganese agar plate from which pure cultures were isolated. Thus, numbers 2, 4, and 5 being the third water from Galveston County investigated, yielded three colonies that were "fished." Number 2 was black, while the two others were brown, and hence are designated as Brown (1) and Brown (2). B-B indicates a brown black colony, i.e., one whose central portion was black and outer portion brown.

reduced, and was practically nil after the third transplanting. Incubation at 37°C. did not appreciably hasten the growth of the organisms.

The medium used in testing the growth of the organisms under anaerobic conditions was that used by Williams and Medaris (5).

All inoculations from the pure cultures were incubated at 37°C., the observations being tabulated in table 2.

CULTIVATION OF THE MANGANESE BACTERIA

The organisms that were isolated by means of the synthetic agar of Kuhr (1) were "fished" to nutrient agar plates and then to the synthetic manganese agar. These pure cultures were maintained on nutrient agar.

These organisms grew profusely on the synthetic media when a small amount of peptone was added. Under these conditions, however, there was no deposit of oxides of manganese.

Another interesting fact was the frequent odor of ammonia, noticed wherever molds or bacterial colonies oxidized the manganese. Molds were quite numerous in some of the waters, though their growth was impaired by incubation at 37°C.

Cultural characteristics

The organisms which oxidized manganese in the presence of the oxygen of the air were very short rods, 1 to 3 microns in length and often appeared in coccoid form. They were Gram positive and motile. Spores developed at the end of 24 hours in all the cultures except three, and at the end of 48 hours in all except one. One culture was apparently a non-sporulative organism.

The general growth on nutrient agar was rather vigorous. The colonies varied appreciably in size and characteristics as is shown in the tabulation. Growth on agar was typified by gray or white colonies, except in one strain, which was chromogenic. The pigment of this strain was yellow. On agar slants the growth was generally filiform; however, other types of growth were also noticed.

No gas was produced from any of the carbohydrate media.

These bacteria were strict aerobes. There was no growth whatsoever on media under anaerobic conditions.

Hydrogen sulphide was not produced, nor were the organisms capable of utilizing citrate.

Gelatin was liquefied by ten of the organisms. The liquefaction in each case was stratiform. Numbers 8, 10, 12, and 14 did not liquefy gelatin. There was a varied reaction toward milk. Seven of the organisms (numbers 1, 3, 8, 9, 10, 12, and 13) produced no curd or peptonization of the milk. A neutral reaction was also noticed in these particular cultures. Only one organism (number 2) produced a hard, solid curd with a turbid whey. The reaction in this case was basic, with very slow digestion of the curd. Two organisms (number 4 and 7) produced a soft curd with a clear whey. The reaction in this case was acid with rather slow digestion. Three organisms (numbers 5, 6, and 11) produced no curd or peptonization of the milk. The reaction was basic.

A general characterization of the bacteria is given in tables 3 and 4. By the use of the various culture media and tests differences in

TABLE 3

Taxonomy of manganese bacteria

NUMBER OF ORGANISM	GROWTH IN AGAR SLANTS	PLATE CHARACTERISTICS (24 HOURS)	BROTH	REDUCTION OF NITRATES	CHROMOGENIC	POTATO
1	Filiform, white	Auriculated, convex, white filamentous	Scarce, +	—	—	Brown, gelatinous
2	Filiform, opalescent	Like No. 1	Scarce, +	—	—	Like No. 4, rhizoid
3	White, filiform	Auriculated, convex, light grey, filamentous	Curd, +	—	—	Brown, gelatinous
4	White, filiform	Like No. 3	Curd, +	—	—	Brown, rhizoid
5	Grey, filiform	Like No. 3	+	—	—	Brown, rhizoid, solid
6	Grey, filiform	Like No. 3	Scarce, +	—	—	Brown, gelatinous
7	Echinulate, white	Rhizoid, convex, light grey, filamentous	Scarce, +	—	—	Like No. 2 and 4
8	Echinulate, opalescent	Rhizoid to myceloid, spreading, light grey, ciliate	Scarce, +	—	—	White
9	Aborescent, grey	Like No. 8, white	+	—	—	White, small
10	Filiform, opalescent	Very slight growth, minute colonies, yellow, small, entire, convex	Light	+	Yellow, +	White, whole
11	Filiform, opalescent	Entire, convex, light grey, filamentous	Scarce, +	—	—	Brown, gelatinous
12	Filiform, opalescent	Like No. 3	+	—	—	Spread, grey
13	Echinulate, grey	Amoebid, convex, light grey with dark spot in center, filamentous	Heavy, +	+	—	Brown, gelatinous
14	Beaded, grey	Like No. 1, clear grey colonies	+	+	—	White, small, entire

strains have been observed. If still other carbohydrate media had been used, further differentiation would undoubtedly have resulted.

Tentative grouping of cultures

Numbers 1, 2, 3, 4, 7, and 12 seem to be sufficiently closely related to be considered as a single species.

Numbers 5, 6, and 11 seem to be sufficiently closely related to be considered as a single species.

TABLE 4
Taxonomy of manganese bacteria

NUMBER OF ORGANISM	LACTOSE	SUCROSE	GLUCOSE	SOLUBLE STARCH CARBOHYDRATE BROTH	STARCH AGAR ACID	MALTOSE	MANNITE
1	—	+	+	+	+	—	+
2	—	+	+	—	+	—	+
3	—	+	+	+	+	—	+
4	—	+	+	+	+	—	+
5	—	+	+	+	+	—	+
6	—	+	+	—	+	—	+
7	—	+	+	+	+	—	+
8	—	—	—	+	+	—	+
9	—	—	+	+	+	—	+
10	+	+	+	+	+	+	+
11	+	+	+	+	+	—	+
12	+	—	+	—	+	—	+
13	—	—	—	+	+	—	+
14	—	—	—	—	+	—	+

Numbers 8 and 13 seem to be sufficiently closely related to be considered as a single species.

Number 9 is considered to be a separate species.

Number 10 is the only chromogenic organism, and is consequently considered as another species.

Number 14 is also considered to be a separate species.

DISCUSSION OF RESULTS

Manganese was found in sixteen of the waters, representing eleven counties, and occurred in concentrations of 0.01 to 3.6 p.p.m. There was some evidence of consistent manganese content in the counties of the central portion, east of Austin, although as a rule the source of water was not a determining factor in the manganese content.

There apparently is no relation between the manganese content of the water and the occurrence of manganese bacteria. In fact, these organisms were definitely found in waters containing no manganese. This would indicate that manganese is not a food requirement and that the power of oxidizing manganese is an independent one.

SUMMARY

A large number of Texas waters have been analyzed for manganese content.

Manganese is not a food requirement for the organisms which oxidize manganese. The oxidizing of the manganese by these organisms seems rather to be an independent one.

Some cultural characteristics of several bacteria capable of oxidizing manganese have been established.

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OXIDATION OF MANGANESE BY BACTERIA

BY O. B. WILLIAMS¹ AND F. W. JESSEN¹

The rôle of manganese in agriculture (1) (2) (3) and its presence in water supplies (4) (5) (6) (7) (8) is important. The purpose of this investigation was to determine whether or not the actual potential (E.M.F.) in bacterial colonies oxidizing manganese could be measured and whether from these measurements the probable state of oxidation of the manganese could be calculated. The electromotive force measurements involved the determination of the voltage of a cell of the following composition: Mg^{++} ($MnCO_3$), Mn^{++} (MnO_2 ppt.) KCl (N), Hg_2Cl_2 (S), Hg (1).

OUTLINE OF PROCEDURE

In order that reliance could be placed in the measurements, they were made with a Leeds and Northrup type K potentiometer, employing a carefully prepared normal calomel half-cell as reference half-cell.

Bacteria which were capable of oxidizing the manganese present in the above mentioned media were obtained from various sources in Texas (9). The organisms were isolated by means of the synthetic medium of Kuhr (7). However, the reaction of the medium was adjusted to a pH of approximately 7 with *Brom thymol blue*.

After inoculation on this "manganese agar" medium, the plates were incubated for about three weeks at room temperature. At the end of this time, small round black or brown colonies appeared on the plates. Incubation at 37°C. did not hasten the growth of the organisms appreciably.

To measure the potential difference of the colonies and the agar on which they were grown, and also the actual potential of the black colonies, a normal calomel electrode was used. It should be noticed that the medium used contained quite a number of salts. Therefore, in order to eliminate, as much as possible, the contact potential

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between the calomel electrode and the manganese X half-cell, an additional agar salt bridge was devised.

The saturated KCl arm of the calomel electrode, and a U-tube fashioned from a small piece of glass tubing were both led into a small test tube. After the small U-tube had been filled with agar (having the same composition as that of the medium), agar used as medium was poured into the test tube. When cool, a layer of paraffin was poured on top of the agar to prevent any undue evaporation losses. The tip of the U-tube filled with agar was drawn to a capillary, which was used as the contact arm of the calomel electrode. This completed the salt bridge of the reference electrode.

The other contact was made by means of a fine platinum wire. This was connected by means of a small mercury cup to the wire leading to the potentiometer.

The platinum wire was placed into the black colony on the agar plate and the bridge of the calomel electrode was placed as near the colony as was possible. This distance did not exceed 5 mm. and was not less than 3 mm.

EXPERIMENTAL DATA

The following data were obtained.

E of cell,

$\text{Hg}_{(1)} \text{Hg}_2\text{Cl}_{2(s)}, (\text{KCl } N); \text{KCl (sat)}$

$\left\{ \begin{array}{l} \text{K, Ca, } (\text{CH}_3\text{COO}^-), \text{NH}_4 \\ \text{Cl, SO}_4, \text{HPO}_4 \end{array} \right. \text{Mn}^{2+}, \text{Mn}^{++} \text{Pt}$

= 0.2802 volts (1st measurement)

= 0.3644 volts (2nd measurement)

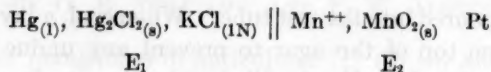
= 0.2021 volts (3rd measurement)

It is to be regretted that no further measurements and checks could be made. This was due to the fact that the organisms failed to oxidize the manganese after being obtained in pure culture and reinoculated twice. They seemed to have lost all ability to oxidize manganese and would not grow at all on the original medium upon which they were isolated. Only one strain grew after being transplanted twice and the colonies in this case were so small that no attempt was made to measure the potential.

The bacteria did not grow under anaerobic conditions, and are hence taken as strict aerobes.

CALCULATIONS AND DISCUSSION OF RESULTS

If, in reference to the cell whose electromotive force has been measured, the contact potential is neglected (as is fairly safe because a saturated KCl bridge was interposed), there is obtained a simplified expression for this cell:



The E.M.F. of E_1 is, of course, that of the normal calomel electrode, -0.2822 volts (10). It is assumed that the oxidized form of manganese is the dioxide. Hence, these measurements were made with the view of checking the experimental values against those calculated on the assumption that the oxidized form of manganese was actually the dioxide.

The value of E_2 is given in Latimer and Hildebrand (11) for the reaction



to be -1.33 volts. The E.M.F. involves molar concentrations of Mn^{++} and H^+ ions. Thus,

$$E_2 = E_0 - RT/2F \ln (\text{H}^+)^4(\text{MnO}_2)_s/(\text{Mn}^{++})(\text{H}_2\text{O})$$

or,

$$E_2 = E_0 - RT/2F \ln (\text{H}^+)^4/(\text{Mn}^{++})$$

The following simplifying assumptions must be made:

1. The Mn^{++} concentration remains constant, due to the large excess of Mn^{++} ion;
2. The pH of the agar does not change appreciably, due to the buffering capacity of the medium; and
3. The contact potential has been eliminated successfully.

The solubility of $\text{Mn}(\text{OH})_2$ is given by Landolt-Börnstein's *Tabellen* (12) to be 2.15×10^{-5} moles per liter at 18°C . Thus,

$$\begin{aligned} E_{\text{cell}} &= E_1 - E_2 \\ &= -0.2822 - (\bar{E}_0 - RT/2F \ln (\text{H}^+)^4/(\text{Mn}^{++})) \\ &= -0.2822 - (-1.33 - 0.02957 \log (10^{-7})^4/1.71 \times 10^{-2}) \\ &= -0.2822 - (-1.33 - 0.02957 \log (5.745 \times 10^{-28})) \\ &= -0.2822 - (-1.33 - 0.02957 (-24.2404)) \\ &= -0.2822 - (-1.33 + 0.7170) = -0.2822 + 0.6130 \\ &= +0.3308 \text{ volts} \end{aligned}$$

A comparison of the measured values, in volts, with the calculated value shows the following:

	E. M. F. (MEASURED)	E. M. F. (CALCULATED)	DIFFERENCE
1	0.2802	0.3308	0.0506
2	0.3644	0.3308	0.0336
3	0.2021	0.3308	0.1287

The first two values give a rather remarkable check; however, the third value seems to vary considerably from the calculated one. If, however, the pH value changed merely one unit, representing a 10-fold change in (H^+) concentration, the calculated voltage would vary approximately 0.118 volts, to give a resultant voltage of about +0.2128 volts. This may explain the discrepancy of the third value. However, this does not seem probable since the medium was adjusted to a pH of approximately 7-7.2. The only other explanation for the discrepancy seems to be that a different oxide of manganese was actually formed. The most probable oxide of manganese would be Mn_2O_3 , which would have given the value of 0.5008 volts for the cell (11).

Latimer and Hildebrand (11), however, state that Mn^{+++} exists only as a very unstable compound, $Mn(OH)_3$, which breaks down (under the conditions of the experiment) to $MnO \cdot MnO_2 \cdot xH_2O$. If this is the case, then, of course, there would be no direct means available for determining to what extent the reaction $Mn(OH)_3 \rightarrow MnO \cdot MnO_2 \cdot xH_2O$ took place. Evidently, such unstable reaction conditions could not be measured by electromotive force measurements.

Also, since this error occurs in the last measurable value obtainable, wherein the bacteria were becoming rapidly incapable of oxidizing the manganese to the dioxide, it seems probable that trivalent manganese might have resulted.

In view of the recent work of A. Simon and F. Fehrer (13) on the hydrogels of certain manganese dioxide hydrates, it seems reasonable to assume that the same conditions probably occur in the oxidation of manganese by bacteria, and that no definite hydrate of MnO_2 is formed. Simon and Fehrer found that there are no definite hydrates of manganese dioxide, and also that manganese dioxide itself is an irreversible colloid and ages very rapidly. This, of course, would not change the actual state of oxidation of the manganese.

Just how this may account for the failure of the organisms to continue the oxidation process remains to be explained. Also, in just what manner the oxidation takes place still remains to be determined.

SUMMARY

1. The work of Kuhr (7) has been confirmed by means of electromotive force measurements.
2. Oxidation of manganese by bacteria has been studied, and the resulting products determined by electromotive force measurements.
3. The organisms that oxidize the manganese are strict aerobes, and, in view of this, oxygen seems essential to the biological oxidation process.

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THE NEW WATER SUPPLY FOR ST. PETERSBURG, FLORIDA¹

By F. W. LANE²

The Pinellas Water Company furnishes water to St. Petersburg from what is called the Cosme-Odesa area which is something like 600 acres in extent. The water is taken from 12 wells, which will average 300 feet in depth. The water from each well varies in hardness and while several wells may be in use at one time different combinations can be put into service so that the hardness can be kept at a desirable degree.

Within the well area there are several fine lakes, the largest of which is Lake Rogers of about 200 acres area. The average depth of water in this lake is not accurately known, but is believed to be about 18 feet, judging from soundings already made. There are about 30 million gallons of water to each foot in depth. Discharge from the well pumps is delivered to the top of a tank holding 2½ millions of gallons, where it sprays through an aerating arrangement which does very satisfactory work. The water in the tank is kept at such an elevation that it can flow by gravity through a 36-inch trunk line of reinforced concrete pipe. This pipe was manufactured by the Lock Joint Pipe Company of Ampere, N. J., at a location about half way between St. Petersburg and the well field and delivered by trucks along the line as needed for laying.

The well pumps have capacities of from 700 to 1000 m.g.d. against total heads of 60 to 100 feet. The pumps are operated by suitable motors, power being furnished by a 220 volt, 3 phase, 60 cycle current. The pumps at different wells may be operated by switches in the pump houses, but normally they are controlled automatically from a well control house by means of combinations of electric apparatus specially designed for the purpose. The well control house is located close by the receiving tank and contains, in addition to the well controls, two Wallace-Tiernan Manual Control Solution Feed

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Vacuum operated chlorinators, type M.S.V.M., a simplex integrating and recording venturi meter of 30 m.g.d. capacity, and a motor driven pump of 12 to 15 m.g.d. capacity. Water from the tank at the well field is delivered into a $3\frac{1}{4}$ million tank located at Washington Terrace just outside of the city limits on the north. From this point the water is pumped into the city lines through $2\frac{5}{8}$ miles of 36-inch lock joint pipe to the junction of 28th St. and 30th Ave. north, where it joins the city distribution. It is reduced at this point to a 24-inch cast iron main extending directly south and a 16-inch cast iron main running east in 30th Ave. The equipment at the Washington Terrace plant consists of one 3 m.g.d., one 6 m.g.d. and one 13 m.g.d. pump, all motor driven. Each pump discharges through an automatic cone check valve. There are two simplex venturi meters each integrating and recording, one of 14 and one 25 m.g.d. The total amount of water passing through the meters, only one of which is in service at a time, is registered on 24 charts.

LEAKS

Before the new supply was turned in we averaged 25 main leaks and about 30 service leaks per month. After the new supply was turned in there were a great many more.

The leaks before new water was turned on all shown below:

	LEAKS IN MAINS	LEAKS IN SERVICES
After September 18.....	106	43
October.....	23	31
November.....	70	62
December.....	113	241

Of the service leaks in December about 70 percent were blown meter gaskets.

January had 49 main leaks and 76 service leaks

February had 39 main leaks and 43 service leaks

Close observation and checking by means of a recording gage seem to justify the opinion that water hammer was the cause of the abnormal number of leaks recorded. When the velocity of a fluid flowing in a line is suddenly stopped as by the abrupt closing of a valve, what is known as water hammer is brought about. If the

valve in question is a check valve of the ordinary type it will generally close with a noticeable jar. The valves at the discharge outlet of the pumps at the Washington Terrace station are automatic and controllable as to time in operating. During the time we were having our epidemic of leaks these valves had not had their best adjustment. The valves are now adjusted to close entirely very slowly, (less than $3\frac{1}{2}$ seconds as was the time of closing at the start) and do not cause water hammer.

The hammer was most noticeable at the junction of the 36- and the 24- and 16-inch city lines, although the bad effects showed at various points somewhat remote. Charts taken on a recording gage at the junction showed some very violent actions.

The joints in the cast-iron lines (city lines) are lead, leadite and cement. The leaks in these lines have all been where lead and leadite were used. As far as we have discovered there have been no leaks at joints in city mains made with cement.

We have cut down our leakage from 45 to 22 percent, we are still lessening it. It may be remarked that a percentage basis for expressing the relations of water accounted for and lost is not just, conditions of supply remaining the same, but allowing the use of no water, would bring about a 100 percent loss. Increased use of water, leakage remaining the same, would cut down the percentage of lost water to a small figure depending on how great the increase became.

HARDNESS

St. Petersburg water of old varied from day to day in hardness and salinity. The hardness ranged from 1200 p.p.m. up and the salinity from 900 p.p.m. up. Soon after the new supply was in use hardness dropped to 195 p.p.m. and gradually down to the present average of about 120 p.p.m. Salinity now runs about 17.5 p.p.m. All complaints of hardness were investigated and after the first six weeks it was found that there was no justification for complaints of hardness, as the water delivered to us was better than the contract with the Pinellas Water Company required. The initial hardness was due mostly to the action of soft-water on such deposits as may have been in our lines after fifteen years use of hard and salty water. Before the new supply was officially in use the Pinellas Water Company supplied the city with many million gallons of water, without cost to the city, for the purpose of flushing out mains and services, and for washing out storage tanks.

COLOR

Many complaints of color were justified and apparently due to the disintegration of old deposits in our mains. Thorough flushing was the remedy. We still have some complaints of rusty and smelly water. These complaints come from remote locations where there is poor circulation and dead ends. These experiences are so common that it seems trifling to take up the time of this convention in mentioning them. They may do some good.

One result coming from the increased rate per million gallons charged for the new water is the installation of local supplies from shallow wells. This suggests a question that may not be an inappropriate one to bring up here, that is, how far is it safe for a city to allow such installations.

In many cases the city water is available by merely opening the curb cock at the meter connection. The meter in most cases has been left connected as a stand-by in case of pump troubles or well failure. If unsafe water is taken from these wells all the plumbing in the premises supplied may become infected. If and when the well supply is out of service and city water is used, it will take up the impurities in the plumbing left there from the use of the well water and the consumer may be subjected to very grave risks. If trouble comes from such a source the city will have to prove that it was caused by the well supply and not from the water supplied by the city. What is the answer?

Some of the hotels in this city use surface well water and are connected to the city supply only through a single valve or curb cock as a precaution against a failure of their private supply. This does not seem right or safe. There is no control over the quality of well water used by large or small users.

VEGETABLE GROWTHS IN WATER SUPPLIES¹

By A. E. BERRY²

Vegetable growths are characteristic of most waters. The quantity present and the resulting influence upon the quality of the water varies tremendously. The effects of these growths may be considered from two angles, the interference with the quality of the water delivered to the consumer, and the difficulty encountered in the treatment process when growths are present in large numbers. Both of these problems are real. The consumer objects to unpalatable or unattractive water. Tastes, odors and color are always resented. The operator of purification works also may be seriously inconvenienced by the presence of these growths. Filter runs are reduced and similar difficulties encountered.

The problem of vegetable growths has long been recognized at many waterworks plants. Laboratory examinations for the detection of these have been established, and local routine methods worked out for their control. In several other plants, however, this problem has not been realized to the full extent. Laboratory analyses are carried out for both chemical and bacteriological constituents. The number of examinations for vegetable growths is, on the other hand, quite limited. As a result of this inadequate knowledge of conditions, complaints and difficulties are likely to be experienced. Microscopic investigations are both justified and important in many water supplies.

The growths found in water supplies include a variety of forms. Some of them are strictly vegetable, others belong to the animal kingdom. There is no sharp line of demarkation between many of these. They vary a great deal in size, appearance and activities. The lowest group is the bacteria. The others vary in size from this to the higher aquatic vegetation, usually regarded as weeds. These latter are, of course, not microscopic. Some of these growths are of

¹ Presented before the Canadian Section meeting, March 7, 1931.

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minor importance while others exercise a major effect upon the quality of the water including changes in taste, odor, color, and difficulties in operation.

Bacteria are not considered in the strictly microscopic examination of water supplies. The groups to which greatest consideration is given comprises the plankton, or free floating organisms, of both plant and animal classification, as well as those higher aquatic forms which are generally attached or stationary. All of the fresh water plankton forms, including both vegetable and animal types, may well be considered in this subject.

PLANKTON GROWTHS

Classification of water plankton has become fairly well standardized. Grouping of these organisms is necessary in order to facilitate discussion and to study their similarities. The classification adopted groups together the plants of similar characteristics. Fungi and various other forms are in this way separated from those plants commonly associated with fresh waters. The animal forms are similarly grouped according to their general characteristics.

A generally accepted classification of plankton growths is as follows: The term algae is commonly used to include all the free-floating plant growths in fresh waters. They are all characterized by the presence of chlorophyll or color and in this way may be distinguished from fungi which are white colorless growths, found most commonly about decaying vegetation. Six classes of algae are recognized in microscopic examinations. These are:

1. Chlorophyceae or green algae
2. Cyanophyceae or blue green algae
3. Diatomaceae—yellow brown in color
4. Phaeophyceae—or dark brown algae
5. Rhodophyceae—or red algae
6. Xanthophyceae or yellow green algae

The microscopic animal groups of most concern in domestic waters are protozoa, crustacea and rotifera. All of these general groups make their appearance under different conditions and exert various effects upon the water supply.

Plankton are widely distributed in nature. They are recorded in all parts of the world and under widely different climatic conditions. They are found in the tropics and in the polar regions. Certain waters, however, offer greater attractions for growth and multiplica-

tion. Generally speaking quiet waters with a suitable temperature and food supply are most desirable. Rain water and ground water are both relatively free from plankton growths. It is only when these waters become a surface supply that growths become prevalent. The schizomycetes, particularly the iron bacteria, are exceptions to this and are found growing in underground pipe systems.

Quiescent surface waters such as lakes, ponds and reservoirs generally contain the greatest number of plankton organisms. They are present at every season of the year. Quiet waters appear to favor their existence. In river supplies the plankton content is generally very much less. These streams which have swift currents and do not drain lakes or reservoirs seldom contain large numbers. The number of microscopic organisms present in rivers is naturally subject, under these conditions, to great fluctuations. Heavy rains or runoffs may sweep this material out into the stream. Slow running streams where backwater expenses or stagnant ponds are found will likewise offer facilities for extensive growth. A rise in the water level with increased velocity will sweep these ponds downstream. The most luxuriant accumulations in both lakes and rivers are generally found along the shores in quiet waters. These may be due to true littoral and benthal growths or they may result from open water growths being washed ashore.

FACTORS INFLUENCING GROWTH

Investigations into limnology and rheology indicate that certain factors in the water have a very definite relationship with the type of plankton found and its multiplication. These factors include among others, temperature, light, wind action, turbidity, food supply, and chemical constituents of the water. These have a very definite bearing upon the magnitude of all aquatic growths.

Temperature

The temperature of natural bodies of water plays one of the important functions in the growth of microscopic organisms. The supply is very low in winter. There is a seasonal distribution which coincides fairly closely with the growth of land plants. Factors other than temperature also exert their influence. Diatoms are normally growths of spring and fall. The optimum temperature is probably difficult to determine accurately, but is thought to be in the neighborhood of 50°F., and lower than the green or blue-green algae. Their

occurrence generally coincides with the period of vertical circulation of the water. Chlorophyceae or green algae, unlike the diatoms, are summer growths, with the maximum in July and August. Their optimum temperature is probably between 60°F. and 80°F. The cyanophyceae or blue-green algae have a seasonal distribution which somewhat parallels that of the chlorophyceae, but with a temperature maximum slightly higher. Temperatures above 70°F. are inclined to result in excessive growths of such organisms as anabaena. The protozoa as a group appear to possess a variable seasonal distribution. Some are most numerous during the warm weather, while others appear to be more influenced by the available food supply. The rotifers are present all year, but appear in greatest numbers between June and November. Crustacea are variable in their seasonal distribution, but generally are found most numerous in the spring. The seasonal distribution of water organisms accounts for the difficulties which are experienced at certain periods in the operation of water works systems.

Effect of light

The presence or absence of light is known to exercise an important bearing on the development of plankton. Diatoms grow very much in proportion to the intensity of the light. Consequently they do not tend to multiply at depth unless the water is very transparent. In quiet waters, however, there is a tendency for these organisms to sink to the bottom. Other plankton growths are known to be variously affected by light. The fact that the greatest growth is generally present in the upper water strata might indicate that most of them are quite sensitive to light. This fact is utilized in the adoption of methods for their control.

Effect of turbidity

Turbidity in water is generally detrimental to algae growths. In some cases it has been applied as a means for their removal from water.

Food supply for plankton

The most important influence on the life of plankton is its food supply. The vegetable plankton require such inorganic substances as water, carbon dioxide, oxygen, nitrates, and phosphates. The true animal plankton must also have organic substances. Nitrogen values serve better than others to predict the fertility of natural

waters with respect to plankton growths. It is a well known fact that as regions become more thickly populated and the drainage entering the water becomes richer in nitrogenous material the growth of algae becomes more luxuriant. Oxygen is also important. Diatoms have shown that they will not multiply in the absence of oxygen. Algae are seldom found in the grossly polluted sections of a water course, whether this is due to lack of oxygen or to food habits is not clear.

EFFECTS OF VEGETABLE GROWTHS

The presence of vegetable growths in water is indicated by several different results. These include odor, taste, color and difficulty of filtration. To this might also be added the growths which are sometimes experienced in pipe systems.

Odors and tastes

Odors and tastes are frequently found in water supplies. They may be due to a variety of causes. Microscopic organisms play an important part in this. It has been definitely established that these odors and tastes may not be due to decomposition products, but rather to the discharge of certain oils from the organisms. These are given off both during growth and during decomposition. These odors are different for the various plankton. A classification of odors from the most important organisms has been pretty well established. In addition to the true algae, odors may be derived from the action of higher aquatic plants growing near the shore. In shallow ponds this growth often becomes very extensive.

Tables are available in current texts indicating the odors of certain particular organisms.

The following organisms have caused trouble other than that connected with characteristic odor: *Fragilaria*, *Melosira*, *Navicula*, *Coelastrum*, *Cladophora*, *Tribonema*, *Spirogyra*, *Oscillatoria*, *Beggiatoa*, *Crenothrix*, *Leptothrix*, *Chara*.

The odors and tastes in water supplies may be due to vegetable growths alone, or to the action of chlorine on these growths. These tastes may at times be very objectionable. The action of the chlorine may bring out tastes which alone would not have been recognized or may intensify those tastes which already exist. When chlorine acts on vegetable growths it may liberate their odor and taste producing oils. These may either remain free or combine with the chlorine to form other compounds.

COLOR IN WATER

The color of a water may be changed by the presence of microscopic growths. Water supplies, so heavily laden with algae, are seldom used for domestic purposes without filtration. Some of the lakes and ponds do harbor growths of such intensity that the water takes on a distinct color. Such waters would seldom be considered for domestic purposes.

EFFECT OF PLANKTON UPON FILTRATION

Plankton growths have a very detrimental effect upon the operation of filtration plants. These are generally seasonal, and correspond to the period when certain organisms are predominating. In open filters, particularly in slow sand plants, actual growths of plankton take place on the filter sand. In modern covered filtration works, the organisms are strained out from the water and then collect on the top of the sand. These accumulations greatly increase the loss of head, and materially reduce the filter runs. A number of plants have encountered this difficulty. The Essex Border filtration plant has been successful in combatting this trouble by the use, during the algae period, of ferrous sulphate and hydrated lime. This raised the minimum filter run from $1\frac{1}{2}$ to more than 10 hours. At Louisville similar shortened filter runs were met by the introduction of artificial turbidity into the preliminary settling basins. This method was successful when several others had failed.

PLANKTON CONTROL MEASURES

The control of plankton in water supplies has been given a great deal of study in recent years. Various methods have been developed. Some have proven efficient generally, while others have had only local successes. These methods belong essentially to two groups, viz., proper construction and operation of reservoirs, and the use of algicides. Open reservoirs are very difficult to keep free from algae. Exclusion of light by covering the reservoir effectively prevents the growth of these organisms. This procedure is however often very costly. Careful stripping and preparation of the soil of natural reservoirs is also a distinct aid.

The use of algicides is practised quite extensively in water supplies. Copper sulphate and chlorine are used for this purpose. These may be applied to reservoirs or elsewhere. The amount of copper sul-

phate required depends on the organisms attacked. Chlorine has been used successfully in a number of plants. The dose of this chemical is also dependent upon the type of growth encountered. While these algicides have generally proven satisfactory this has not always been the case and reports as to their ineffectiveness are to be found.

CONTROL OF IRON BACTERIA

Difficulties are sometimes met by growths in ground water systems. These are different from the algae which grow only where light can be had. The most important of these growths is the iron bacteria, the most prominent one of which is *Crenothrix*. It thrives best in the dark, and in water which contains little or no oxygen, but a good deal of carbonic acid. It has the power to oxidize certain forms of iron and precipitate it. This accumulation in the pipes seriously interferes with their carrying capacity. It may occur in any part of a system carrying iron-bearing waters. Fortunately this is not encountered frequently in Ontario. Deferrization of the water has been adopted as a control measure in some places.

ODOR NUISANCES FROM ALGAE

In recent years a number of places have experienced very objectionable odor nuisances from the decomposition of algae in open waters. These have occurred in lakes, rivers, and ponds. Generally they are present only in confined bays where the water is shallow and the temperature high. So long as the algae are living no very disagreeable odor occurs. When decomposition sets in, however, very offensive conditions result. The odor is not unlike sewage. Assertions have been made that sewage was responsible for the odor. These worst conditions have appeared in the vicinity of population centres. These growths are apparently greatly augmented by the food supplied from the sewage and drainage. Decomposition sets in when the food supply in the bay or confined area becomes depleted. In some places black sludge 18 inches in thickness has been found. The use of algicides under these conditions is difficult. Wave action tends to disperse the chemicals before a sufficient contact period has been reached. Removal of the living growth onto the shore where it is permitted to dry seems to offer a satisfactory method.

TOXIC EFFECTS FROM ALGAE DECOMPOSITION

While algae have seldom caused any serious poisonous reactions there are cases where the decomposition of these growths has caused the deaths of animals drinking the water. In a small lake in Hastings County, Ontario, an extremely heavy growth of anabaena, a blue-green algae colored the water a distinctly greenish-blue shade. It was noticed that this growth in one of the bays died and underwent decomposition. Some twenty head of stock including cows and sheep drank the water and died very shortly. The products given off in the decomposition were extremely toxic. A very limited number of similar cases have also been recorded in the literature.

Plankton growths in water may generally be regarded from the standpoint of a nuisance rather than an actual danger. There can be no doubt, however, that justifiable complaints from the water consumers will result from the presence of some of these. The difficulties experienced in the treatment of the water also augment the need for their control. Where laboratory facilities for examination of this kind are not available locally samples may be submitted to the Provincial Department of Health. It is difficult to combat such a nuisance effectively until a thorough knowledge is had of the organisms present.

WATER TREATMENT AT ATLANTA, GEORGIA¹

BY PAUL L. WEIR²

The Atlanta Water Department has been obtaining its supply from the Chattahoochee River since 1890. The river's 1500 square mile drainage area is advantageously remote and very sparsely settled, with a run-off during periods of dry weather relatively high compared with other streams. Despite last summer's general deficient precipitation, it yielded an abundant supply. Its unusually high turbidity may be attributed to the fact that it flows through a territory highly agricultural. This river carries a nominal amount of pollution and is satisfactory from a sanitary standpoint. The water is soft and low in mineral content.

CHARACTERISTICS OF RIVER

The suspended matter in the Chattahoochee River varies over a wide range. The turbidity varies from 25 in dry weather to 5000 p.p.m. in the wet season. The coefficient of fineness of suspended matter varies from 0.7 to 1.1.

The river carries little dissolved coloring matter and at no time of the year is it a factor in computing the required chemical dosage.

The distribution of hard and alkali water of various degrees of hardness throughout the country in general occurs in twenty-seven States, comprising about 75 percent of the total area of the United States. The localities providing so called "soft" water are confined to nineteen States, located in three groups, the northwest, northeast, and southeast, respectively. Of these, the southeastern section predominates in area, with Georgia occupying the geographical center. The average total hardness of Atlanta's supply is 10 p.p.m. expressed in terms of calcium carbonate.

¹ Presented before the Southeastern Section meeting, April 7, 1931.

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TREATMENT

The chemical treatment of Atlanta consists of presedimentation, followed by coagulation with alum and lime, and disinfection with liquid chlorine.

There are two presedimentation reservoirs, each functioning independently of the other. One has a capacity of 176,000,000 gallons and is held in reserve when an exceedingly low head in the second reservoir may necessitate its use. It is practically free from turbidity and has an abundant plankton growth. In this region plankton, or algae, if permitted, may grow abundantly the year round in practically all storage reservoirs. In this reservoir, where in many instances not more than 25 percent of the water is replaced annually, the growths may be exceptionally heavy. Throughout the winter and spring months the plankton consists mostly of Crustacea and Rotifera, and seldom exceeds 10 per cubic centimeter. Beginning in early summer the development of *Anabaena* and *Asterionella* may exceed 50 per cubic centimeter and if not controlled may remain until mid-winter. The removal from the water of the organisms themselves adds a very heavy burden to the filtering units. Only a small portion of the organisms, either dead or alive, can be recovered in the coagulating basins after the water has been treated.

The control, rather than the elimination, of plankton requires a moderate dose of copper sulphate. The reservoirs are dosed about three times a year using from 0.5 to 5 pounds per million gallons of water.

The effectiveness of chlorine in the destruction of these organisms indicates that possibly such treatment would be more useful than copper sulphate. It is remarkable, however, that the average water works operator does not encounter more difficulties with algae, in view of the fact that one acre of reservoir water yields the same amount of foodstuff as an acre of fertile soil.

The second reservoir has a capacity of 216,000,000 gallons and receives its entire supply directly from the turbulent Chattahoochee River and discharges it into the chemical mixing chamber. This reservoir is used continuously and after the raw water enters the influent it flows through the entire treatment process by gravity, with a marked degree of economy in the control of the final product. Over a period of twelve years we have found that this reservoir smooths out the turbidity peaks about 41 percent. Free carbonic acid is reduced about 25 percent. Algae offer little difficulty, due

to the constant changing of the head and average retained turbidity is sufficient to prevent appreciable growth. Phenolphthalein alkalinity shows a gain of 10 percent in plant influent over that of the reservoir influent. Phenolphthalein alkalinity is increased in the presedimentation basins by the activity of the algae. The algae in the process of growth extract the carbon dioxide from the bicarbonate of the water leaving normal carbonate.

Coagulation

The mixing chamber is of the "around-the-end" type giving a total travel of 1664 feet. At the present rate of treatment, which is 32,000,000 gallons daily, the retention period is 40 minutes with an average velocity of approximately 0.5 foot per second. This chamber is designed on the basis that best results can be obtained by gentle agitation combined with a time element sufficient to permit the reaction of the applied chemicals to be completed. Alum is added in the first section of the chamber. The raw water pH varies between 6.6 and 7.2 and this is lowered to between 6.0 to 6.6 in obtaining coagulation. In the outlet pass of the chamber, lime is introduced in sufficient quantities to raise the pH of the coagulated water to between 7.0 and 7.3.

The chemical house is built on the north wall of the entrance flume of the mixing chamber and contains 4 dry feed machines, 2 of which are used for alum and 2 for lime; but they are interchangeable. Chemicals are stored on the second floor of the building and discharged into hoppers, which extend from the lower to the second floor. The dry-feed machines are driven by water motors, the discharge from which is used to carry the chemicals into the mixing chamber. Every ten days one alum and one lime machine is replaced by a cleaned machine. As soon as these machines are out of service they are immediately dissembled and carefully cleaned of all adhering chemical, in addition, the small discharge shields and mixing boxes are given a coating of pitch, which inhibits the action of acid on the metal. This work is carried out consistently every ten days with the result that we realize a maximum operating efficiency and a minimum amount of operating difficulty.

The floc begins to form in the mixing chamber before the water has traveled one-fourth the distance through the chamber, and when it leaves the chamber it is fully formed. It settles out quickly when it reaches the coagulating basins, making the basins more effective, since no part of these are used in completing the reaction.

There are five coagulating basins having a combined capacity of 13,000,000 gallons and providing a theoretical retention period of 10 hours at 32,000,000 gallons daily rate. The pH of the influent of these basins averages about 7.3, and due to the settling out of suspended particles, and to the gradual increasing effect of the lime added in the mixing chamber, the supernatant effluent is increased to 7.6.

Algae cause little trouble in these basins, but whenever it is found necessary to destroy it chlorine is added directly to the raw water in the mixing chamber by dry feed. A residual of 1 p.p.m. is retained for about three hours. This treatment proves entirely satisfactory in eliminating algae that might be present in either the mixing chamber or the coagulating basins.

Disinfection

Chlorine is applied to the effluent of both the gravity and the pressure filter plants, Wallace and Tiernan vacuum type chlorinators are installed in both plants. In order to insure continuity of operation all the chlorination equipment is in duplicate. To each million gallons of filtered water 1.3 to 1.5 pounds of chlorine are added. This dose is effective in eliminating after-growths that may occur in the distribution system. Although the amount of chlorine added to the filtered water is small compared with other plants, we find it imperative to keep our machines clean and in good working order at all times. At no time is the water permitted to enter the mains without being chlorinated. It cannot be emphasized too strongly that it is far preferable to operate on the side of safety and always have an excess of chlorine, than to permit contaminated water to enter the system. The responsibility of providing a safe and pure water rests upon our shoulders.

Operating data

Approximately 802,000 pounds of alum were used by the Water Department last year, all of which was manufactured by the Georgia-Louisiana Corporation. The dose of alum varied from 1.67 to 0.24, the average over the year being 0.47 g.p.g. Two hundred eighty-six thousand pounds of lime were used containing an average 99 percent water soluble calcium oxide. The dose used varied from 0.30 to 0.02, the average for the year being 0.17 g.p.g. About 18,000 pounds of chlorine were used during the year.

The average alkalinity in the raw water was 11.0 and in the filtered 16.0 p.p.m. The average pH in the raw water was 7.0 and in the filtered 7.4. The turbidity of the raw water varied from 3000 to 25 p.p.m., with an average of 150 p.p.m. for the entire year. The gravity filters gave minimum runs, between washings, of 60.0 hours with maximum runs of 248 hours, with the yearly average of 140 hours for the entire plant. The bacteria in the raw water averaged 324, in the coagulated water 9.6, in the filtered water, 1.2, and in the tap water, 0.4 per cubic centimeter. *B. coli* was present in 90.1 percent of all the 0.5 cc. raw water samples. No trace was found in the tap water. In the raw water free carbon dioxide was present from 1.0 to 8.0 p.p.m. No trace was found in the tap water. Although Atlanta is an inland city, geographically, its water contains 320 parts per billion of iodine. The average temperature of the air for the year was 62°F. and of the water 60°.

DISCUSSION

CHAIRMAN WIEDEMAN: I want to ask Mr. Weir to tell you about some rather interesting experiences he has had in the last thirty days in his new position, particularly the experience which he has had with periodic dissolved iron in the raw water. I think the case is rather unique and it might be of interest to you to hear it.

MR. WEIR:² The water at Lyman, S. C., must be zero turbidity and free from all objectionable minerals. The raw water is pumped from the Little Tiger River. At 7:00 in the morning we may have a turbidity of 100, at 7:15 we may have it at 600 or 1000. We have to catch our water as it comes and give it the proper chemical dose. We made a few experiments. We tried adding lime to the raw water and found that was effective in removing the iron. We tried other experiments, but they have not served well enough to give an account of them. We did find it possible to get water comparable to distilled water. One mile above us is a steam power plant of 40,000 H.P. capacity. The entire flow of the river is often used for condensers. The temperature of the water is raised about 10°F. adding to the difficulties of maintaining a floc. Periodical boiler blowdown adds objectionable minerals which further complicate operation, but we are taking steps to impound this blow-off water and feed it in constant quantities to the stream which will enable us to handle it more easily. Our work has not progressed sufficiently to enable me to give you much data on it.

THE LONDON WATER SUPPLY¹

By JOHN T. CALVERT²

In B. C. 55, Julius Caesar landed on British soil and at that time, as far as any extant records show, there was no London. There were embryo cities where the early Britons had settled to a small degree, but London was not one of these, and its foundation is almost certainly due to the military and commercial instincts of the Romans and their realization of the value of the site. London is said to have begun its existence with the construction of a bridge across the Thames by the Romans so as to form a dry route from the north to the south at a point which had previously been used as a ford. St. Albans was at that time one of the most important Roman encampments and situated perhaps 20 miles to the north of London, and records indicate that the city grew mainly as the port for St. Albans. London lies in the London Basin, a flat geological formation drained by the lower Thames. The basin rises much more steeply to the north than to the south so that the northern approach to the site was easy, whereas the southern approach was through difficult marshy land. The excellent navigation facilities afforded by the river also support the theory of London being St. Albans' port.

The rise of the City of London, including not only the city proper, as restricted to the small though vastly important portion, but also the surrounding suburbs which constitute the capital city of the British empire, is chiefly due to its very favorable position on the Thames. This is the second largest river in England and provides an excellent harbour inland so as to be well sheltered as regards climate and yet sufficiently near to the coast to be easily accessible from the continent. As trade grew, so London grew and at the time of the Norman Conquest in 1066 London was a walled town and the Abbey had already been founded by Edward the Confessor. The King made it his seat and it has subsequently remained so except for

¹ This paper was presented in partial fulfillment of the requirements in Municipal Sanitation at the Massachusetts Institute of Technology.

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the few stormy years of the revolution and the period of the Common wealth and for a short while during the visit of the Great Plague. Its population has consistently increased, except perhaps for the devastation exerted by the Plague and the Fire in 1665 and 1666 and it has spread, unlike American cities, outwards to cover larger and larger areas and to absorb into itself what were once entirely separate communities. It is at present the largest European city, as measured either by area or population, it is one of a few ruled by a monarchy and commercially is probably the most reliable and influential.

The climate is mild, having a mean annual temperature of 50°F., with no extreme variations and although the mean annual rainfall is only 23½ inches, London suffers from a comparatively large percentage of rainy days. Its fogs are traditional and although they certainly live up to their reputation in intensity, their occurrence is not as frequent as legend demands. The latest census gave a population of seven and a half million people, covering an area of 126 square miles.

Navigation is not the only consideration which results in the formation of a town on the banks of a river, and since a supply of water for such variety of purposes is an essential and not a luxury to a community, it is natural that towns should have sprung up where such is available. Nowadays, as, for example, in Los Angeles, it is possible to erect a town under the most unfavorable conditions of water supply, but before present day methods had been so efficiently elaborated, a plentiful and agreeable source of water was an important factor in the situation of the towns.

HISTORY OF THE WATER SUPPLY

London was admirably situated in this respect, for not only was the Thames itself an abundant supply, but there were numerous springs which rose in the London Gravel in the vicinity and so provided a widespread source. The water from these springs flowed as streams into the river and such streams as Tyburn, the Westbourne, the Holborn, and the Ravensbourne have left their names behind them as a street or a district, or in some now historic landmark. Many of these streams still exist, but they have now all been covered and most of them unfortunately converted into large intercepting sewers. In the twelfth century wells were developed in the city and Holy Well, Clerk's Well (Clerkenwell) and St. Clement's Well are familiar names to a Londoner of the twentieth.

In the thirteenth century the inhabitants became more exacting and more fastidious and were no longer content to fetch their water from the streams. Conduits were built which conducted the water directly into the houses and when some of the streams were covered by buildings themselves in 1236, the magistrate purchased permission to convey the waters of the Tyburn into the city by means of leaden pipes and in 1285 a great conduit was erected in West Cheap. The Tyburn Springs later proved insufficient and in 1438 for a consideration of two peppercorns paid on the Feast of Saint Peter, the Abbot of Westminster gave permission to the Mayor of London to take water from the Manor of Paddington.

As a business enterprise on a large scale, Peter Moris first undertook to supply London with water from the Thames and in 1581 put up a pump under the first arch of London Bridge and was able to throw water over St. Magnus's Steeple to the great admiration of the Mayor and others who had assembled. This continued as an extremely profitable business under changing ownership until 1822 when competition became too severe and it was merged with other water companies. As early as the beginning of the seventeenth century a rival sprang up when in 1606 the City of London obtained parliamentary powers to bring water from springs in Hertfordshire, north of London, and after being allowed to lapse for two years the project was adopted by Sir Hugh Myddleton who constructed the aqueduct 38 miles long in parts suspended over the valleys, and consequently known as the boarded river, and in parts cut deeply into the ground. This continued to supply its customers adequately and as the supply by the corporation decreased, the New River Company became increasingly prosperous and finally was forced by the demand, to extract water from the River Lee, a tributary of the Thames running south through Hertfordshire. In 1630 another scheme for bringing water from the Lee was organized, which is of interest, not from an engineering point of view, but from its method of financing, since funds were raised by the promotion of a public lottery licensed by Charles I.

From the formation of the New River Company for a long period there was no novel advance and the progress made consisted in the foundation of a large number of companies, their rise and fall and amalgamation with other companies, with sundry minor improvements left as an indication of former existence. All these obtained their water from the river Thames and pumped it directly to the con-

sumer and differed only in the points where the water was extracted from the river and the districts which the companies served. One other source was tapped, the deep wells dug and developed by the Kent Water Company.

There are two landmarks which are of supreme importance during the development prior to the present era which might be designated as that of the Metropolitan Water Board. In 1829, Charles Simpson, the Engineer to the Chelsea Waterworks Company, introduced for the first time sand filtration of water, a process adopted for its improvement of the appearance of the water and developed only much later for its improvement in the bacterial quality. This process is now employed for the treatment of the water for many large cities all over the world and yet its effect on the appearance of the water for which it was originally introduced is hardly ever considered.

In 1854, the pollution of the Thames became so serious that the water companies were forced by act of Parliament to move their intakes above the tidal portion of the river. Previously, the only form of treatment had been a wire mesh screen introduced mainly for the purpose of protecting the pumps and the pollution was not sufficient to be considered a menace. Pollution of the Thames has progressively increased as the parts round and above London have become more thickly populated, and recently a suggestion to build a huge treatment works for the whole of the sewage of Middlesex which at times would equal the natural flow of the river has inspired A. P. Herbert to write.

Sweet effluent, dear Father Drain,
Whose generous bosom doth contain,
A lot of oil, a little rain,
And all the muck of Middlesex.

This type of ode, he claims, will in the future replace the many beautiful poems which have been written to the Thames.

At the very end of the last century there were eight separate companies supplying water to different areas of London and six of these were drawing water from the River Thames. The oldest was the New River Company which supplied water from the river Lee and from wells in Hertfordshire, the six supplying water from the Thames were the Chelsea Company, the East London Company, the West Middlesex Company, the Grand Junction Company, the Southwark and Vauxhall Company, and the Lambeth Company, and finally there was the Kent Waterworks Company which supplied an

untreated water from the deep wells in Kent. These companies were supplying a total quantity of 190 million gallons per day for an estimated population of nearly six million with an average consumption of 32.4 gallons (39 U. S. gallons) per head.

At this time, there was a considerable amount of discussion as to the adequacy and the potability of the water then being supplied to London and after much agitation a Royal Commission was appointed to enquire into the present and future supply of water to the Metropolis. One interesting scheme which was seriously considered by the Commission and, although rejected by them, may yet have a future, was the Welsh Scheme and is worthy of notice. Its most enthusiastic supporter was Sir Alexander Binnie, then chief engineer to the London County Council, who wanted to take over the whole of the London water supply and then in order to supplement the local supply, construct a huge aqueduct right across England to transport water from the Welsh Hills into a reservoir to be built in North London. They brought evidence to show that the project was in every way feasible and would provide a purer and more plentiful supply than could be obtained from the Thames.

The Commission, however, did not favour the scheme and instead recommended that all the various water companies should be transferred to a central authority (not the London County Council), which should be carried on as a semi-representative public body and decided that the Thames, Lee and deep wells with storage capacity would serve London efficiently for the next forty years.

THE METROPOLITAN WATER BOARD

As a result of the recommendations of the Royal Commission, the Metropolis Water Bill was passed by Parliament in 1902. This stipulated that the Water Companies should be taken over by compulsory arbitration by a Metropolitan Water Board which would issue bonds to pay for the capital of the companies and was to be formed by nomination of representatives from the various elected public bodies which were concerned with the supply. There are sixty-six members of the board, maintained by the London County Council, the Middlesex, Kent and Surrey County Councils, the Thames Conservancy Board, the Lee Conservancy Board and other similar bodies.

Under the supervision of this Board, the water supply of London has progressed by leaps and bounds in reliability, quantity, quality,

pressure in mains, etc. They have increased the amount of treatment so as to be sure of an invariably safe supply, the capacity of the treatment plants so that all plants are not always working at full capacity, the amount of storage available by the construction of raw water reservoirs and service reservoirs, they have installed new and larger pumping equipment and by treating the whole area as a unit, have linked up the various districts. Under the old companies each district was independently supplied by its own company without any intercommunication of mains and when shutdowns occurred a whole district was deprived of its water supply. This state of affairs in fact caused the Royal Commission to submit a preliminary report emphasizing this danger and strongly recommending an immediate linkage of the different supply systems of the various companies.

The Board also initiated a department of water examination and research and appointed Dr. (now Sir) Alexander Houston as Director of the Department. It is impossible to over-emphasize the immense importance of this step and the value that it has proved to the water supply of London. The existence of such a department is a sign of progress and of a desire to serve the public as satisfactorily as possible, but, in this case, the high esteem in which this department of the Board is held all over the world is due to the character and individuality of its Director. He is a remarkably interesting man who inspires everyone connected with him with loyalty to himself and to his work and whose fertile mind is an endless source of information and of original ideas. The department carries out routine tests, both chemical and bacteriological, of all the waters supplied and is able to control the operation of the treatment works, but more important is the research work carried out under Sir Alexander Houston. His first researches were on the viability of typhoid bacilli in river and treated water leading to the conclusion that "uncultivated" typhoid bacilli die rapidly under natural conditions and it is perhaps due to these researches that storage reservoirs are regarded now, not only as a reserve supply, but also as a definite form of water treatment having an extremely beneficial effect on the quality of the water. His researches on rapid sand filtration led to their introduction as prefilters in many plants and his work on sterilization led to the use first of lime and later of chlorine, not only in London but in many British cities. They have also carried out academic work on the isolation of pathogens and the employment of various enrichment

media for *E. coli* isolation and have made an exhaustive study of algae and other water growths.

The Metropolitan Water Board of London now supplies seven and a half to eight million people with water at a rate of nearly 40 gallons per capita per day (45 U. S. gallons). Of this, 150 million gallons per day are extracted from the Thames between Staines and Hampton, 65 from the Lee and about 45 million gallons per day from deep wells either in Kent or on the original New River supply.

When the Metropolitan Water Board was inaugurated each company had its own reservoirs which in most cases sufficed merely to supply the demand at times when water could not be taken from the river. There were no reservoirs of great capacity, the highest being of nearly 300 million gallon capacity and supplies the East London Waterworks Company. The total capacity at the time was 4,000 million gallons. Partly as a result of the recommendations of the Royal Commission and partly as a result of research work indicating the advantages of storage, the policy of the Board has been to increase the storage capacity to its maximum possible. Parliamentary permission had been obtained by three companies conjointly to construct reservoirs at Staines and this work was completed by the Board with the result that in 1903 the opening of the Staines Reservoir increased the storage capacity of Thames water by 3,340 million gallons. In 1907 reservoir and treatment works at Walton on the Thames were completed and a further addition of 1200 million gallons capacity was made. In 1911 a reservoir at Molesey having a capacity of 1,100 million gallons was also provided for Thames water and in 1913 a reservoir north of London at Chingford was opened by the King and Queen. This has a capacity of 3,000 million gallons and takes the water from the river Lee. In 1914 contracts for new and larger reservoirs at Littleton and Laleham were let, but the war caused cessation of work and they were not completed until 1925. The plans were altered to form one huge reservoir lower down the Thames than the Staines reservoir and having a capacity of 6,500 million gallons. This reservoir is known as the Queen Mary Reservoir and the one at Chingford as the King George reservoir. The storage capacity of the Board now is 19,657 million gallons and represents a storage period between two and three months for London and sufficient to supply the whole world with a gallon of water per head for ten days. This represents an ample reserve from the quantity point of view and since one month's storage is believed to be sufficient to kill all harmful bacteria the factor of safety in this respect is quite high.

Storage, however, is not relied upon entirely to protect the health of London and treatment plants of new and improved types have been another sign of the efforts of the Board to provide efficient service. The companies were comparatively well equipped with slow sand filtration plants and the progress in treatment works has been in the introduction of rapid sand filters and chlorination. The sand beds occur at various points down the Thames corresponding to the various points where the companies originally extracted their water and also at Stoke Newington for the filtration of the New River supply. At the Chelsea Works and the Lambeth and Vauxhall works there are slow sand filters having a capacity of 70 m.g.d. as originally owned by the companies. In 1926 at Walton on the Thames, in conjunction with the reservoir construction, 18 rapid sand and 6 slow sand filters were constructed to deal with 30 m.g.d. and in 1929 at Kempton Park 24 primary rapid sand and 12 slow sand filters capable of dealing with 17 m.g.d. were constructed. The Board has a total of 178 filter beds covering an area of 176 acres.

Sir Alexander Houston reported that he did not consider rapid sand filtration alone as being sufficient to ensure perfect safety and at both plants even though slow and rapid filtration are used, chlorination equipment was also installed. Not all of the water is so treated and the amount depends upon the conditions of the raw water. New River water is chlorinated during the winter months, the Thames water from the Hampton, Walton and Kempton works is chlorinated continuously and from other works as occasion demands. The total amount chlorinated is around 79 m.g.d.

The distribution system has also been vastly improved. Large mains have been laid and especially since the war large numbers of mains up to 8 feet in diameter have been put down so that now the Board possesses 7,000 miles of distribution mains. Pumping equipment has been improved and at Kempton the pumping station is one of the largest in Europe. There are 278 engines having a total of 47,000 horse power. Service reservoirs have been increased in number and size from a capacity of 244, when the Board was formed, to the present capacity of 321 million gallons.

Thus the progressive policy of the Metropolitan Water Board has removed to a future date any fears as to the inadequacy of London's water supply, and the researches of the Director of Water Examination have ensured the safety of the millions of inhabitants of and of visitors to this great city.

THE FLOW OF WATER IN PIPES¹

By ROBERT W. ANGUS²

The engineer on a waterworks system is frequently confronted with the problem of figuring the loss of pressure in a pipe carrying a certain volume of water, or of knowing the pressure at a place in a town that will result from a specified pumphouse pressure. As a matter of fact, waterworks piping systems are more or less complicated, being made up of many cross connecting mains and branches and the calculation of the losses and pressures is rather difficult. A few very common examples will be worked out in some of the more simple cases, and these will illustrate the principles involved.

In almost all problems dealing with pipes the velocity of the water must be known, and a simple method of finding it will, therefore, first be given. If the flow is in imperial gallons³ per minute the velocity may be found by multiplying the flow by 0.49 and dividing by the square of the pipe diameter in inches; if the flow is in millions of gallons per 24 hours the multiplier is 340.6. Thus, in a 10-inch pipe carrying 700 gallons per minute the velocity is $0.49 \times 700 \div 10 \times 10 = 3.43$ feet per second, and if the flow in a 20-inch pipe is 10 million gallons per day the velocity is $340.6 \times 10 \div 20 \times 20 = 8.51$ feet per second.

Another quantity called the velocity head is also most useful, and will be explained at once, so that problems may be solved. This is a convenient term used to express the energy in each pound of water due to its velocity, and while it merits more than a passing mention, space only permits a statement as to its meaning. If the velocity, as found in the above method, is squared and divided by 64.3 (or multiplied by 0.0155) the velocity head is found. Thus, in the first example the velocity head is $0.0155 \times 3.43 \times 3.43 = 0.183$ feet, and for the second example the velocity head is $0.0155 \times 8.51 \times 8.51 =$

¹ Presented before the Canadian Section meeting, March 12, 1931.

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³ One imperial gallon equals 1.2 U. S. gallons.

1.12 feet. The principles of hydraulics may now be applied to a few actual and very common cases.

FRICTION LOSS IN PIPES

One of the most common problems is to find the drop in pressure when water is flowing in a pipe. This loss may be readily computed by dividing the length of the pipe by its diameter (both of these being in inches or in feet, but both must be in the same units) and multiplying this quantity by the velocity head and by a constant depending on the size of pipe, and also on its age and the velocity of the water in it. Tables of this constant are available in many textbooks on hydraulics, but as the calculations to be undertaken are to be approximate, and within a few per cent, only some values of the constant are given. For fire hose the value may be taken as 0.0225, for 1-inch new pipe it varies from 0.0317 to 0.0245, for 2-inch new pipe from 0.03 to about 0.024, the larger values in each case being for the lower velocities and the smaller values for the higher velocities; for 6-inch pipes the values are 0.025 to 0.022, and for 24-inch pipes they are 0.019 to 0.018, roughly. These values are for new pipes and they gradually increase as the pipes become old and dirty till they are about 50 per cent higher than the above values, when the age is 15 years, although for fire house there is little change.

Fire hose

If a line of $2\frac{1}{2}$ -inch fire hose 200 feet long is discharging 200 gallons per minute then the velocity is $0.49 \times 200 \div 2.5 \times 2.5 = 15.68$ feet per second, and the velocity head is $0.0155 \times (15.68)^2 = 3.81$ feet, and the friction loss is $0.0225 \times \frac{200 \times 12}{2.5} \times 3.81 = 82.3$ feet. If the pressure in the hose at the hydrant is 190 feet, that at the base of the play-pipe, if at the same level, is $190 - 82.3 = 107.7$ feet, or $107.7 \div 2.31 = 46.6$ pounds per square inch.

Water pipes

Now suppose it is desired to pump water through a new pipe 4000 feet long, 12-inch diameter, and having 10 bends. The discharge is to be into a reservoir with its water surface 100 feet above the pump, the latter having a delivery of $2\frac{1}{2}$ million gallons daily. What pump pressure is necessary for this service?

Here the velocity is $340.6 \times 2.5 \div 144 = 5.91$ feet per second, and

the velocity head is $0.0155 \times (5.91)^2 = 0.542$ feet. Also the length of the pipe is 4000 times its diameter, and it may be assumed that the loss in each bend is about 30 per cent of the velocity head, so that the total loss is $0.021 \times 4000 \times 0.542 + 10 \times 0.3 \times 0.542 = 47.2$ feet. The pump pressure must, therefore, be that required to lift the water the 100 feet plus the friction, or $100 + 47.2 = 147.2$ feet, which is equivalent to $147.2 \div 2.31$ or 63.5 pounds per square inch. This pressure will be increased one foot for each foot that the water rises in the reservoir.

The pump horse power required may be found by multiplying the daily discharge in millions of gallons by the pressure in feet and by 0.21 and then making allowance for the efficiency of the pump. In the above case the horse power delivered into the water would be $0.21 \times 2.5 \times 147.2 = 77.3$, or the pump horse power would be $77.3 \div .75 = 103$ H.P. if the pump efficiency is 75 percent. Of course, allowance would have to be made for the suction lift.

EFFECT OF END CONNECTIONS

The method of connecting a branch pipe to a main, or of connecting a pipe into a reservoir or tank, may have much or little to do with the rate of flow, depending on whether the pipe is short or long. Typical connections are the standard end, the inward projecting end and the bell-mouthed end. If the connection is such that the end of the branch is perpendicular to and just exactly flush all around with the inside wall of the tank, or reservoir, or main, as in figure 1, the connection is said to be by standard end and the loss at entry of the water into such a pipe is 50 percent of the velocity head in the pipe. If, however, the end of the pipe projects some distance inside the reservoir or main, as in figure 2, the loss is 78 percent of the velocity head, whereas if the end of the pipe is rounded like a bell mouth, as shown dotted in figure 2, the loss is from 5 to 25 percent of the velocity head, depending on the amount of rounding at entrance, but 15 percent may be taken as an average. One or two examples will show the meanings of these quantities.

Short pipes

Suppose that a new 6-inch horizontal pipe 20 feet long is to be used to discharge water from a reservoir into the atmosphere, and let it be assumed to be 4 feet below the water surface, how much water will be discharged when the control valve is wide open? Since the

discharge is freely into the atmosphere, and the water leaves with a certain velocity, the velocity head corresponding to it is lost. Thus, the entire 4 feet is used up in friction at entrance to the pipe, in friction in the pipe and in the velocity head of the water leaving. Now suppose the connection is made by standard end, figure 1, then

$$4 = 0.50 \times \text{velocity head} + 0.022 \times \frac{20}{6/12} \times \text{velocity head} + \text{velocity head} = (0.50 + 0.88 + 1) \times \text{velocity head},$$

or the velocity head is 1.68 feet, from which the velocity is $\sqrt{1.68 \div 0.55} = 10.4$ feet per second. The flow is, therefore, $10.4 \times 6 \times 6 \div 49$ or 765 imperial gallons per minute.

On the other hand, if the pipe projected into the reservoir a foot or so, figure 2, the figures would be $4 = (0.78 + 0.88 + 1) \times \text{velocity head}$, which gives a velocity head of 1.50 feet and a flow 720 gallons

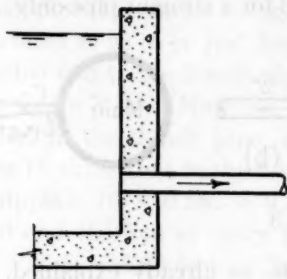


FIG. 1

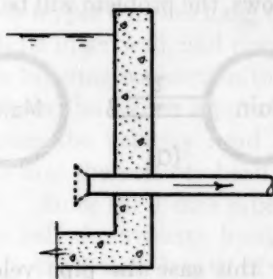


FIG. 2

per minute. Again, if a bell-mouthed end is used the relation is $4 = (0.15 + 0.88 + 1) \times \text{velocity head}$, and this corresponds to a flow of 830 gallons per minute. Thus, this pipe may be made to carry anywhere between 720 and 830 gallons per minute, depending on how the end is made and connected into the reservoir.

Had the pipe been only 10 feet long then the flow may easily be shown to vary between 794 and 932 gallons by changing the end connection. In most cases one form of end connection is just as easily made as another, and it is clear that there is a vast difference in the results obtained.

If the pipes are very short the loss in the straight part of the pipe may be ignored and the total loss would then be that at entry added to the velocity head. For instance, if the total length of the pipe or mouthpiece in the above problem is reduced to 2 feet, then, with the

standard end the velocity head is $4/1.5 = 2.67$ feet, corresponding to a velocity of 13.1 feet per second and a flow of 964 gallons per minute, while in the bell-mouthed end the velocity head is $4/1.15 = 3.48$ feet and the flow is 1100 gallons.

Long pipes

The above example shows the effect of the end connection when the pipe is short, and it evidently is very marked in such cases, but if the pipe is a very long one the form of the end connection makes little or no difference. Thus, suppose water is being delivered through 300 feet of old 2-inch pipe to a tank, and let the pipe draw its water from a 12-inch main in which the pressure is 60 pounds per square inch; it is required to find the height to which the water will rise in the tank for a flow 50 gallons per minute. While it is easy to include the effect of elbows, the problem will be solved for a straight pipe only.

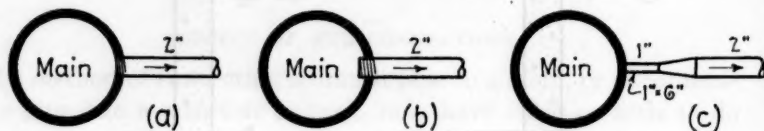


FIG. 3

For this case the pipe velocity is, as already explained, $0.49 \times 50 \div 4 = 6.12$ feet per second and the velocity head is 0.582 feet. Further, in finding the friction loss in the pipe the constant to be used as a multiplier of the velocity head is $1.5 \times 0.026 = 0.039$ since the pipe is old. Several possible main connections are shown on figure 3.

In the first example suppose that the 2-inch pipe is screwed into the main so that its end is just exactly flush with the inside of the latter, as at (a) figure 3. In this case the total loss in the entry end, in the straight part of the pipe and in velocity head is $0.5 \times 0.582 + 0.039 \times \frac{300}{2/12} \times 0.582 + 0.582 = 41.7$ feet, and since the pressure in the main is 60 pounds per square inch or $60 \times 2.31 = 138.6$ feet, the height of the water in the tank will be $138.6 - 41.7 = 96.9$ feet above the main. Had the pipe projected inward into the main, as at (b) figure 3, the only difference would have been that the 0.5 would have increased to 0.78 and the level of the water would have been 96.7 feet,

or practically the same as before. Evidently the bell-mouth end would add so little that it would not be worth its cost.

This example, and it is typical of many such, shows that the end connection is of little moment where the pipe is long compared with its diameter, and this is practically always the case where the length is over 1500 times the diameter. This leads to some interesting results. For instance, suppose that the above 300 feet of 2-inch pipe is to be connected to the main under pressure, but that a 2-inch tapping machine is not available, the largest size within reach being 1-inch. If it did not involve much trouble and expense the tendency would be to tap four 1-inch pipes into the main and connect them all to the 2-inch line, since this would give the full area in the connection, but that this is not at all necessary, is shown by an illustration.

Take the illustration where the connection between the main and the 2-inch pipe is made by a single 1-inch nipple 6 inches long, tapped into the main so as to be just flush with its inner wall, and connected at the other end to the 2-inch pipe by a tapering connection to avoid loss, see figure 3 (c). Now the velocity in the 1-inch nipple is four times that in the 2-inch pipe, and hence the velocity head in the former is 16 times that in the 2-inch, so that the velocity head in the 1-inch nipple is $16 \times 0.582 = 9.31$ feet. Since the 1-inch pipe has a standard end the loss at entry to it is half the velocity head in it, or $9.31 \times 0.5 = 4.66$ feet. The loss in the 6-inch length of nipple is negligible, and also that in the tapering connection from the nipple to the pipe need not be considered, since it will also be very small.

The loss when the single 1-inch nipple is used for the connection will, therefore, be $0.5 \times 9.31 + 0.039 \times \frac{300}{2/12} \times 0.582 + 0.582 = 46.1$ feet and the water in the tank will be $138.6 - 46.1 = 92.5$ feet above the main. This will be 4.4 feet lower than before, or the pressure on the 2-inch pipe near the tank will be reduced about 2 pounds square inch, which is relatively little considering the connection. If this 1-inch nipple is well rounded or bell-mouthed at entry the loss would only be $0.15 \times 9.31 + 40.85 + 0.582 = 42.8$ feet, and the tank level would be $138.6 - 42.8 = 95.8$ feet above the main, i.e. only one foot lower than if the 2-inch pipe had been tapped in, as in the first case.

In setting up elevated storage tanks great care must be taken to place them at the correct height. In the illustration just given the water level has been found with the flow stated, but it must be

remembered that if the flow stops, and the valves are left open so that the tank is still connected to the 12-inch pipe, the water will rise in the tank to a height corresponding to the pressure of 60 pounds, or 138.6 feet, in the main. Taking the first case where the friction loss is 41.7 feet, it is evident that unless the tank is 41.7 feet deep and placed at proper height, it will either be empty under full draft or will overflow when the draft stops. This trouble may readily be provided against by the use of suitable valves and floats placed in a tank not so deep as 41.7 feet.

WATER METERS

If it becomes necessary to meter the discharge then the resistance of the meter will produce an appreciable effect. The loss of head in ordinary meters, excluding those of the Venturi type, varies with the style, discharge, and size of meter, and will also vary in different meters of the same make and size, especially in the smaller ones. This loss varies from about four to six times the velocity head in the pipe, but is by no means confined within these limits. For the purpose of illustration the loss will be taken as five times the velocity head.

In the last problem solved the loss in the meter alone would be $5 \times 0.582 = 2.91$ feet, and the level of the water in the tank would be lowered by that amount after its installation. Since the loss per 100 feet of pipe in that case is $0.039 \times \frac{100}{2/12} \times 0.582 = 13.62$ feet, the meter produces the same loss as 21.3 feet of pipe.

To take a further illustration, suppose that a new 1-inch pipe 70 feet long is being used to draw water from a tank, the discharge being into another open tank and the end of the pipe being 30 feet below the level of water in the upper reservoir. If the upper connection is by standard end, it is required to find the discharge, there being 3 elbows. If the pipe is ordinary wrought iron its diameter will be 1.05-inch.

Using the methods already explained, the total head of 30 feet is lost at entrance, in the elbows, in the straight pipe and in the velocity head, and hence $30 = \text{velocity head } (0.50 + 3 \times 0.3 + 0.027 \times \frac{70}{1.05/12} + 1)$, using slightly less than the average of 0.0317 and 0.0245 as the pipe multiplier. Therefore, the velocity head in the pipe is 1.25 feet and the velocity is 8.97 feet per second, which corresponds to a flow of 20.1 imperial gallons per minute.

If a meter is placed in the line then an additional factor of 5 must be added to those in the above relation and this will reduce the velocity head to 1.035 feet, corresponding to a velocity of 8.16 feet per second and the discharge will be 18.3 imperial gallons per minute.

INTAKE PIPE

Only one more illustration of the use of the methods explained above will be given. Suppose that a waterworks intake was originally made of 24-inch pipe 900 feet long extending out into a lake from a well on shore, but that later on, the shore water having become polluted, the intake was extended by the addition of 1000 feet of 30-inch pipe. If the top of the pipe at the well is 4 feet below lake level, how much water will the intake carry after it has been in service 15 years?

In this case the total available loss of head in the system is 4 feet, for when the well is over 4 feet below the lake, the well end of the pipe is partly unwatered and its discharge will fall off because the pipe is not full of water. The total loss is then $0.028 \times \frac{900}{2} \times \text{velocity}$

head in 24 inches $+ 0.0258 \times \frac{1000}{2.5} \times \text{velocity head in 30 inches}$

(note that the multipliers 0.0183 and 0.0172 are increased 50 per cent to 0.028 and 0.0258, respectively, to allow for old pipe). But the area of 30-inch pipe is 1.563 times that of 24-inch pipe, and hence the velocity in the latter is 1.563 times that in the 30-inch, that is, the velocity head in the 24 inches is $1.563 \times 1.563 = 2.44$ times that in the 30-inch pipe. The above may then be written

$$0.028 \times \frac{900}{2} \times 2.44 \times \text{velocity head in 30 inches} + 0.0258 \times$$

$$\frac{1000}{2.5} \times \text{velocity head in 30 inches} = 4 \text{ feet}$$

Thus, the velocity head in the 30-inch is 0.0974 foot, so that its velocity is 2.50 feet per second. By the rule given at the beginning of this paper the delivery is $2.50 \times 30 \times 30 \div 340.6 = 6.60$ million gallons per 24 hours.

A little consideration of the problem will show that almost 75 percent of the total loss is in the 24-inch pipe and if it is desired to improve the intake without putting in an entire new one, the plan that would involve least expense would be to reduce the loss in the

inner 900 feet. Of course, this pipe might be replaced by a new and larger one, but during construction this might interfere with the supply, and a very decided improvement would be made if a new pipe was laid parallel to the 24-inch pipe, and of the same length as the latter, the new pipe being connected to the well and also to the old intake, by a proper connection, just where the original 24- and 30-inch pipes join.

In order to illustrate the problem, let the new pipe be 30-inch diameter, 900 feet long, then it is desired to find what will be the

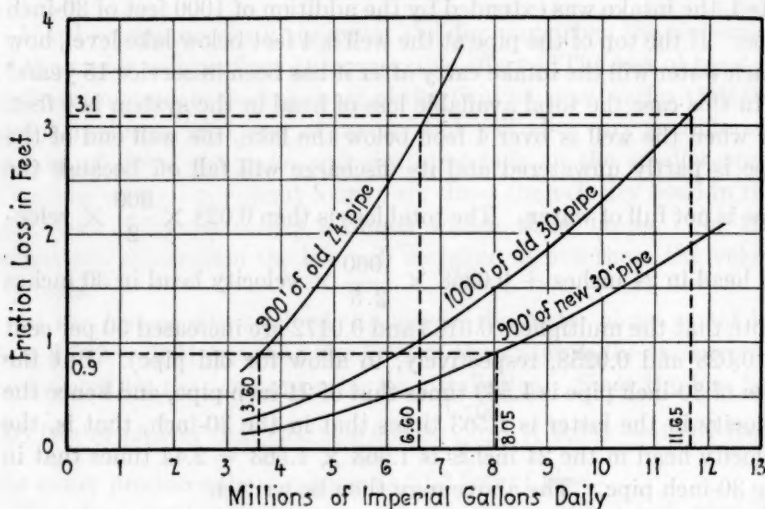


FIG. 4

delivery of the intake with the same difference of levels as before between the well and lake water, that is 4 feet.

This problem may be solved in various ways, but one of the simplest is by means of curves. If the losses in the old 24-inch, the old 30-inch and the new 30-inch are separately plotted on a sheet of cross section paper the new discharge may be found. To plot these curves make up a table showing for each flow the loss of head. Thus, with a flow of 5 million gallons per day the velocities in the 24- and 30-inch pipes are 2.96 feet per second and 1.89 feet per second, respectively, and the corresponding velocity heads 0.136 and 0.0555 foot. The losses in the several pipes are, therefore:

$$\text{In 900 feet of old 24-inch pipe } 0.028 \times \frac{900}{2} \times 0.136 = 1.72 \text{ feet}$$

$$\text{In 900 feet of new 30-inch pipe } 0.0172 \times \frac{900}{2.5} \times 0.0555 = 0.343 \text{ feet}$$

$$\text{In 1000 feet of old 30-inch pipe } 0.0258 \times \frac{1000}{2.5} \times 0.0555 = 0.573 \text{ feet}$$

These calculations locate one point on each of the curves on figure 4. A number of other points are calculated in the same way and the three curves shown are plotted.

These curves may now be used to find the flow through the intake pipe under various conditions. Taking the original intake consisting of 900 feet of 24 inches and 1000 feet of 30-inch pipe, then with a flow of 6 million gallons the loss is 2.47 feet in the 24-inch piece and 0.85 foot in the 30 inches, making a total loss of 3.32 feet. Again, with a flow of 6,600,000 gallons per day the loss is 3 feet plus 1 foot = 4 feet. After the new 30-inch pipe has been laid from the well to the old junction of the 24- and 30-inch pipes, so as to work in parallel with the 24-inch pipe, the capacity of the intake will be very much increased and may be readily found from the curves.

With the two parallel pipes the loss of head between the well and their junction must be the same in each and the curves show how much each one will carry. For example, when the loss in each is 1 foot the 24-inch piece carries 3.8 million gallons and the 30-inch pipe 8.5 million gallons, or a total for the two of 12,300,000 gallons per day, which is the quantity which must be carried by the outer piece of 30-inch pipe, and it will produce a loss in the latter of 3.45 feet, as read on the curve. The total loss in the intake would, therefore, be 4.45 feet, which is more than that allowable. A few trials show that with a loss of 0.90 foot in each of the inner pipes the flow in the 24- and 30-inch pipes is, respectively, 3,600,000 and 8,050,000 gallons, or a total of 11,650,000 gallons, and for such a flow the middle curve shows that the loss in the outer 1000 feet of 30-inch pipe is 3.1 feet. Thus, the total loss in the intake is 4.0 feet and its capacity evidently 11,650,000 gallons per day.

The above problem shows the very great advantage of the new piece of 30-inch pipe, for it has raised the capacity 77 percent. The curves provide a very excellent method of studying all problems of this kind.

THE COST OF FALSE ECONOMY¹

BY ROBERT C. WHEELER²

The dictionary says that economy is, "Disposition to save or spare, carefulness in outlay; freedom from extravagance or waste."

On the one side is extravagance, on the other side is parsimony.

The ideal path is down the middle of the road, but in a good many instances the fear of criticism causes those responsible for the operation of a water works to pare the budget too close as regards the operation and maintenance of the plant and to fail to make reasonable provision for extending the plant to meet the requirements of the consumers. They call it economy, but in reality it is false economy.

It represents a failure to follow the fundamental rules of business in keeping ready for whatever reasonable demands are apt to be made on your plant. That is more than sound business doctrine; to the possessor of a monopoly it is a duty.

"If you can delay—stave off—a piece of work for fifteen years you have saved the price of it in interest; take a chance, you may not need it."

These are tempting formulas, particularly to those whose only punishment will be to have to admit that they guessed wrong, that nature or the good Lord failed them. To the people who really have to pay the bill it is an altogether different matter.

If consideration were given to all the factors in the case with a just weighing of the probabilities, many of the chances would not be taken.

It is not possible to foretell exactly in each particular case, but the operator or engineer with experience in other similar problems knows that in a certain proportion of the cases the undesirable does occur and that in a certain proportion of cases the risk is greater than the possible saving warrants.

There is just enough of right in these catch phrases to make them dangerous if used without a careful consideration of the odds and the consequences.

¹ Presented before the New York Section meeting, April 22, 1931.

² Consulting Engineer, Albany, N. Y.

I am going to give a few of the sources of cost of false economy in water supply.

EXAMPLES OF FALSE ECONOMY

In the first place it is not always true that if you can delay a project for 15 years you have saved the cost. This is particularly so in water supply, because if you do a piece of work to-day with the idea that it may be done over in 15 years, you may find that the territory and location of the work have so changed in 15 years that the cost of doing the work is two or three times greater than it would have been in the first place.

During this period streets may have been paved and other structures built, which greatly increase the complexity and cost of the work.

If the work is simply put off altogether it may be found that, in addition to the increased difficulty of construction, such items as real estate, rights of way and water rights have greatly enhanced its value.

In these instances, where we are not even considering the effect of insufficient facilities, there was no actual saving at all; the increased construction cost more than offset any temporary reduction in interest charges. In actual practice the temporary facilities may give out at a time when it is practically impossible to renew them, for financial or other reasons.

In one instance when the life of a semi-permanent pipe line (built according to the theory that the saving in interest charges would rebuild the line when it was worn out) came to its useful end there was no disposition on the part of the authorities to replace it until typhoid germs passing through the weakened structure took their toll of lives and the city paid the bill.

Another phase of the same subject is one where proper facilities to meet the demands of service are not provided.

Everyone is running along about his business when suddenly there is a shortage of water. There has been a small amount of interest saved by not constructing a new reservoir or enlarging the old one, but what is the result?

First, there is a mad scramble to get emergency equipment. Then at once there is the expense of installing and operating emergency equipment, and it is very rare that the consumers receive anything like a satisfactory supply either as regards quantity or quality.

Occasionally the authorities refuse to recognize the serious condition until the community is actually without water.

On one such instance announcements were given to the newspapers saying that there was no shortage whatsoever, but that the whole affair was malicious gossip on the part of political enemies.

Then there is the effect on the business life of the community through the curtailment of the supply. In some instances people are without work due to the closing down of plants, in other cases the factories turn out an inferior product which hurts their reputation. In one case not long ago a considerable quantity of material in process of manufacture was ruined through the introduction into the system, without warning, of an emergency supply of inferior water. This company recently has been acquired in the formation of a combine and this particular plant is being scrapped. Probably no one in the community will know to what extent difficulties with process water played in making the decision as to which plants would be operated and which would not. In another city, as a result of a similar shortage of water in the factory supplies, it was necessary to close down the factories for a time, many people were thrown out of employment and the superintendent was replaced.

Frequently we hear the comment as justification for postponing some necessary improvement. "Oh well, if we run short we will just cut down on the factories for a while." Every now and then the worm turns, but the trouble is that the right people are seldom the ones who get the reaction.

In a small way a good many people are hurt financially who say little about it, the garages are not allowed to wash cars and so lose income and the washer is out of a job, citizens are not allowed to sprinkle lawns and gardens and lose their investments and the fruits of their labors. The towns and cities lose the revenue or else the consumer (through minimum charges) is obliged to pay for something he does not get.

It is poor business and false economy.

And besides that there is the hazard to life and property.

Polluted supplies are pumped into the mains, sterilized as well as possible to be sure, but not equal or equivalent to the water the consumer has a right to expect from a monopoly which does not have the stimulation of competition.

How often do we hear with regard to a fire, there was not enough water?

In many cases, where the annual revenue is low, the actual cost in money of the emergency equipment necessary to meet the crisis is a serious item, but in any event it is only a part of the real cost to the consumers.

At present we are occupied with the design of a new plant because the owners of the existing plant failed to provide proper fire protection. The trouble was not that they failed once to make adequate provision to meet the needs of their customers, but that they kept on failing until the people finally decided to build their own plant. The possible cost to them is the loss of the business.

These are glaring examples. There are many others in which the errors in judgment are not so obvious and the payment for which is not exacted so dramatically, but they are similar and the price is there just the same.

The little decisions that come up every day are vastly more important in the amount of money wasted, although not so spectacular.

When we allow ourselves to be guided in the purchase of materials, services or equipment by the first cost rather than the cost per mile of travel, per gallon of water pumped or some similar measure, which takes into account the cost of operation and maintenance as well as the initial investment, we are making our own contribution to the cost of false economy.

WATER ANALYSIS, ITS INTERPRETATION AND RELATIONSHIP TO WATER PURIFICATION¹

BY NORMAN J. HOWARD²

On many of the smaller water works plants chemical and bacteriological analysis figures are frequently furnished to the plant superintendent or operator, who, on account of not having received technical training in chemistry and biology of water, is sometimes at a loss to interpret them. The writer was asked to write a short paper, dealing with the subject in simple language, and it is hoped that this paper will serve the purpose for which it was prepared. On account of the direct relationship of the analytical figures to water treatment, brief reference is made to methods sometimes involved.

PHYSICAL CHARACTERISTICS

The physical characteristics, which include color, turbidity, taste and odor will first be discussed. Water in its natural state is colorless or of a pale blue color, but its contact in nature with certain substances may cause it to take up color. By a colored water we understand, therefore, that water has taken up coloring matter which may be directly derived from the products of decomposing vegetation, from peaty soils, from swampy land or from mineral salts. The nature of such color varies according to the local environment. It is now generally conceded that organic color in an acid water is colloidal in character, and has negatively charged ions, which are readily precipitated by an electrolyte having a positive electrical charge. This is mentioned as showing why alum and iron salts when applied to water cause precipitation of the color in the floc formation. Treated water having a color of less than 16 parts per million is barely noticeable, although in swimming pools this amount of color can be seen against a white background.

Turbidity is matter suspended in water, consisting chiefly of clay,

¹ Presented before the Canadian Section meeting, March 11, 1931.

² Director, Filtration Plant Laboratories, Department of Public Health, Toronto, Can.

silt, and finely divided organic matter and living microorganisms. Its degree and coefficient of fineness are always important factors. Turbidity is measured by comparison with standards prepared according to the U. S. Geological Survey methods, while the coefficient of fineness is calculated by dividing the weight of suspended matter in the sample by the turbidity. Modern filtration systems properly designed and operated, are now able to completely eliminate all turbidity from the water.

On account of the close relationship of taste and odor senses, this subject will be considered under one heading. They may be caused by either organic matter in solution or suspension, vegetable matter, living microorganisms, by chlorine or the action of chlorine on some substance present in water. Odors caused by decomposition of organic matter are called vegetable odors, which title usually covers a large variety of odors. Taste and odor may be overcome by numerous methods, including aeration, chemical treatment of living microorganisms or over-chlorination. Faint odors in cold water are greatly intensified by heating to a temperature of approximately 190°F. and then covering up the vessel and allowing to stand a few minutes before testing. Odor from excessive doses of chlorine are noticeable, but such water will rarely taste unless the chlorine residual exceeds 0.2 p.p.m. If taste occurs after chlorination it is usually caused by the action of chlorine on some substance present which may have resulted from the decay or breaking up of living organisms, some of which freely liberate oily substances capable of causing intensive taste and odor, or from the formation of substitution compounds such as chlorophenols. The latter taste may be prevented by the application of ammonia before chlorination or by the super- and dechlorination method.

REACTION

The reaction of water is extremely important, not only on account of the coagulating difficulties often experienced in treating either a soft or a very hard water, but also because of the corrosive action of certain supplies. Years ago the reaction was expressed as either acid or alkaline to certain reagents, but within the past few years the term hydrogen-ion concentration has replaced this method of expression. Hydrogen-ion concentration in plain language represents the true concentration of acidity or alkalinity. Water which is neutral, is said to have a pH (potential of hydrogen) of 7, below this figure is the

acid range and above is the alkaline range. The chief difference of computation between the old method of expression and the hydrogen-ion concentration method, is that the last named measures the true acidity rather than the total quantity of acid present. One of the best definitions was made a few years ago by Frank Green of Little Falls, N. J., who defined hydrogen-ion concentration as being "the measurement of the minute amounts of hydrogen which are present in the ionic state due to electrolytic dissociation." Many modern filtration plants having difficult waters to handle, have found the hydrogen-ion concentration method of great value in plant control.

OTHER CHEMICAL CONSTITUENTS

In addition to the above, the sanitary analysis of water as a rule, includes the estimation of nitrogen as free and albuminoid ammonia, nitrates and nitrites, oxygen consumed and dissolved, chlorides, alkalinity, hardness and total solids. The mineral analysis is also quite important, particularly from the industrial viewpoint.

To understand the significance of free and albuminoid ammonia, representing as they do the carbonaceous and nitrogenous matter present in water, we must consider the source of supply under examination. Free ammonia is the direct product of decomposing organic substances and voidings in sewage. While there may be many reasons for variation in free ammonia, any unusual increase above the normal quantity must be regarded as suspicious, because in water subject to pollution, the bacterial content is found to closely follow variations in free ammonia. As previously mentioned knowledge of source of supply is very necessary for intelligent interpretation of results. The albuminoid ammonia is defined in Standard Methods, as the nitrogen equivalent of ammonia formed or liberated from nitrogenous matter by the action of alkaline permanganate in water after expulsion of ammoniacal nitrogen by distillation. The quality of various types of water can sometimes be gauged by its ratio to free ammonia. In normal water, the ratio will often be found to be approximately 1:1 to 3:1, while in sewage polluted water, the free ammonia may be very much higher than the albuminoid figure. The amount of organic pollution may also be determined by the oxygen consumed in a permanganate solution incubated at a suitable temperature. In this test we determine the amount of oxygen used up by a measured quantity of water. In polluted water this test is of great value, but in waters containing oxidizable mineral substances the

test may be of limited value unless allowance is made for the reduction caused by such substances. By oxygen dissolved is meant the amount of oxygen present in water. Under favorable conditions water may be super-saturated. The amount of oxygen present, depends entirely on the organic pollution and the degree of plant and vegetable growth in the water. In addition, temperature plays an important part, the amount of dissolved oxygen decreasing with a rising temperature. Certain types of active algal growths are said to liberate oxygen in water, while all forms of decomposing vegetation and organic matter, particularly in stagnant water, slowly use up and may completely exhaust the dissolved oxygen, leaving the water foul tasting and smelling.

Chlorides are usually expressed as chlorine, the chlorine being in combination with sodium as sodium chloride and may also occur as calcium and magnesium chlorides. The chlorides in water are derived from the atmosphere, from various sources of pollution, especially sewage, certain trade wastes, and from the soil and rock formations. Pure water contains very small quantities of chlorides, and statistics show that with increasing pollution of stream and lake supplies, there is a progressive increase in the chlorides, which in the case of contaminated waters is found to correlate closely with bacterial pollution. Water can contain as much as 500 p.p.m. without being objectionable as regards taste; over 700 parts will cause a perceptible salty taste. If the chlorine is present as magnesium or calcium chlorides in amounts in excess of 50 p.p.m., the water will have a corrosive effect on boilers.

Nitrates expressed as nitrate nitrogen, are regarded as a direct result of the oxidation of nitrogenous animal matter, and generally indicate previous sewage pollution. A few years ago this test was regarded as essential in water analysis, but nowadays unless present in excessive quantities, little importance is placed upon it. On the other hand nitrites occurring as nitrite nitrogen, are of great importance as they are present in recently polluted water and suggest incomplete oxidation of the organic matter. Unless caused by the reduction of nitrates, which is possible in the presence of certain metals such as iron and zinc, nitrite when present in small quantities in water is clearly a danger indication.

We come next to certain gas which occur in water, chief of which is carbon dioxide known as carbonic acid, which may be present as free or what is known as half-bound. The free carbonic acid is pres-

ent in a majority of waters and is liberated upon boiling. The resultant accumulation in boiler water may cause pitting and corrosion. The necessity for treatment of boiler water is thus apparent. Free carbon dioxide can be completely removed by suitable treatment. The half-bound consists of one half of the carbon dioxide in calcium, magnesium and sodium bicarbonates. Under treatment the bicarbonates decompose into carbon dioxide and calcium, magnesium and sodium carbonates. Other gases of importance include hydrogen sulphide, which usually disappears upon exposure of water to the atmosphere. The reduction of sulphate by crenothrix and other organisms is said to cause hydrogen sulphide.

MINERAL CONSTITUENTS

Hardness in water is an important test particularly from an industrial viewpoint. What is a hard water is a question commonly asked. Softened waters are treated, so that the residual hardness is usually between 90 and 100 p.p.m. Hardness represents soap consuming power and does not directly indicate the amount of calcium and magnesium in water. The permanent hardness is that which remains after boiling while the temporary hardness, consisting chiefly of calcium bicarbonate, is removed by boiling. Hardness of most waters is due to four compounds held in solution. Calcium bicarbonate, commonly called limestone, calcium sulphate, commercially known as gypsum, magnesium bicarbonate, known as magnesite, and magnesium sulphate known as epsom salts are the chief minerals. By treating hard waters with lime or the lime-soda ash process, the calcium and magnesium salts are precipitated. In the zeolite process, the zeolite sand consists of sodium, alumina and silica. The calcium and magnesium in the water exchange places with the zeolite sodium, the zeolite losing its sodium and the water its calcium and magnesium.

Among other minerals found in water are calcium carbonate and chloride, magnesium chloride, iron and alumina sulfates, iron, alumina and silica, and sodium sulphate. Calcium carbonate, known as chalk or carbonate of lime, is the commonest form in which lime is present in water. In the presence of carbon dioxide it dissolves in water and forms bicarbonate of lime. The muddy deposits found in boilers are chiefly calcium carbonate. Calcium chloride is very soluble and occurs in natural waters. It does not form scale, but in the presence of certain sulphates forms calcium sulphate which as previously mentioned is highly objectionable. Magnesium carbon-

ate, commonly known as magnesia, is more soluble than calcium carbonate but is usually found as the bicarbonate due to the presence of carbon dioxide. Magnesium chloride and nitrate are sometimes found in water and are very corrosive when present in boiler water, causing pitting and grooving. Should iron and alumina sulphates be present in water in undecomposed form they will be extremely corrosive. Iron may be present in various forms in natural waters either as a ferric or as is usual ferrous carbonate kept in solution by carbon dioxide. The iron may be soluble or insoluble in colloidal form, the latter being rare. Water containing iron carbonate usually will become discolored upon exposure to the atmosphere due to oxidation. Red water sometimes occurs in water mains, due to certain corrosive properties which have not been corrected at the purification works. Certain microorganisms known as iron bacteria which include leptothrix and crenothrix take up iron oxide from water and may cause a deal of trouble. The presence of iron in amounts in excess of 0.1 p.p.m. is regarded as objectionable in a treated water. Alumina and silica both occur in water usually in small quantities and generally speaking may be regarded as unimportant. Silica, however, when present in certain quantities may cause boiler scale.

ORGANISMS

Brief reference should be made to the microscopical and bacteriological examination of water. The part played by living organisms, sometimes known as plankton life exclusive of bacteria, is considerable, chiefly in stored waters and various types of sand filters. Such organisms are divided into many groupings too numerous even to outline in this paper. Their presence may, however, do much to indicate the reasons for objectionable tastes and odors in water, to explain the rapid loss of head in filters, the variation in chemical analyses of water, and give much information in the studies of fish and aquatic life.

The bacteriological examination of water may include a large number of tests, each of which may prove of definite significance. In general, bacteria are minute forms of vegetable life occurring in increasing numbers following pollution. When dealing with water filtration we are chiefly concerned with two groupings, one being aerobic and the other anaerobic. The aerobic group require oxygen and play an important part in filtration by reason of their oxidative properties. The anerobic group which thrive in polluted water can-

not live in presence of oxygen. They cause decomposing substances to form ammonia and nitrogen and can materially alter the chemical composition of water. The common practice in the bacteriological examination of water is to determine the total number of bacteria present in certain quantities, regardless of type, which will grow at body temperatures under artificial conditions, and in addition, to determine whether the *Bacterium coli* is present in certain concentrations, sometimes designated as the *B. coli* index. By making bacteriological examinations of the raw, filtered and chlorinated water the progressive degree of purification can be determined. It is sometimes asked why tests are not made for the *Bacillus typhosum*. The isolation of this organism in water is extremely difficult and inasmuch as *B. typhosum* and *B. coli* are usually present in sewage polluted waters the isolation of the colon bacillus is sufficient to indicate the probable presence of the more dangerous organism, which is said to cause typhoid fever.

Various standards exist as to the final quality of water. In Europe, the *B. coli* figure aimed at is a negative test in 100 cc., while in America, the amount is 50 cc. This figure depends entirely on the source of supply, the purification and sterilization process used, and whether the plant is laboratory controlled. All of these are of considerable importance. Standards cannot be too high, particularly in the polluted water which sanitarians are nowadays called upon to purify. There remain many details untouched, but if this paper has been the means of partially assisting those unfamiliar with water analysis and its interpretation, it will have been of service.

SOCIETY AFFAIRS

THE MINNESOTA SECTION

The meeting was called to order at 10:00 A.M. on October 30, 1931, in the Tahitian Room, Hotel Lowry, St. Paul, M. J. Howe, Chairman, presiding. Seventy-six registered, 31 of which were from out of town and 45 from St. Paul and Minneapolis.

Honorable Gerhard J. Bundlie, Mayor of St. Paul, gave the address of welcome. The highlights of his talk were the responsibilities of water works operators in serving their communities and the part they are to take in the return of prosperity. The response was made by M. J. Howe, Chairman.

The paper on "Treatments for the Prevention and Removal of Tastes and Odors" was delivered by John R. Baylis, Filtration Engineer, Chicago, Ill. A discussion on tastes and odors followed led by C. L. Ehrhart, Superintendent Water Works, St. Cloud; Arthur F. Mellen, Filtration Engineer, Minneapolis Water Department; Frank Raab, Bacteriologist for the Minneapolis Water Department. This concluded the morning program.

The luncheon was held in the Silver Room with about 40 members present.

Ole Forsberg, Vice President, took charge of the meeting at 12:30. He called on the famous after-dinner speaker, Mr. E. R. Patericke, who hails from Lake City. His talk played chiefly on the subject of "Pep and Fraternity" and although humorous, it was realistic. He stated that the U. S. leads in coöperation, fraternity, industry, and loyalty to the flag. He honored Thomas A. Edison, nationally known inventor.

The minutes of our last meetings were read and a report on financial standing followed.

Mr. Forsberg then appointed an Auditing Committee, to check the financial report, consisting of Messrs. Janzig, Crowley, and U. J. Seibert.

A Membership Committee, consisting of Messrs. Waterous, G. A. Johnson, Lasley, Frank Woodward, and Raab, was also appointed.

Messrs. Childs, Nehring and Kelly, who were selected as the Nominating Committee, announced their choice of officers for the ensuing year. They elected Ole Forsberg, Chemist of the Oliver Iron Mining Company, as Chairman, John Druar, Consulting Engineer in St. Paul, as Vice-Chairman, and C. L. Ehrhart, Superintendent of the St. Cloud Water Works as Trustee.

Mr. Forsberg then acknowledged his election. He discussed briefly the necessity of the members coöperating with the secretary and treasurer.

A round-table discussion took place regarding the time and location of our next annual meeting. Mr. Ehrhart suggested that it be held in St. Cloud. Geo. A. Johnson suggested that it be held at this same time of the year and this was unanimously approved. Mr. Childs, who is a member of the North Dakota Section, said that their fall meetings were most successful.

Mr. Thompson said that the year 1913 was the last time the National Convention was held in the Twin Cities. He moved that our secretary send the National Committee an invitation to hold the 1933 meeting in our state. Mr. Childs stated that the 1933 meeting is slated to be held in Chicago in conjunction with the World's Fair. It was agreed that we should put in a good bid each year until we are successful.

The meeting was adjourned at 1:50 P.M. after deciding that the next meeting take place at 2:00 in the Tahitian Room. Thompson invited the members to register at the desk for the trip Saturday morning at 9:00 to the St. Paul Filtration Plant and other points of interest.

The next meeting was called to order at 2:05 P.M. by Ole Forsberg in the Tahitian Room. Mr. T. H. Hooper, Superintendent of Water Works at Winnipeg, Canada, was the opening speaker.

Much interest was shown in the following round table discussions:

1. Cost of water pipe laying (6 to 8 inches per foot) including valves and hydrants in our state under first contract in smaller cities, led by M. J. Howe, Lake City.
2. Water works troubles during past year, led by J. A. Jensen, Minneapolis.
3. What should be done for old employees when they become unfit for active service, led by Julius A. Schmahl, St. Paul.
4. The effect of last summer's drought on surface water supplies in Minnesota, led by O. E. Brownell, Minneapolis.
5. Pollution of well supplies, led by O. E. Brownell, Minneapolis.
6. Meter testing, led by Geo. A. Roder, St. Paul.

A motion picture "Underground Service Installation of Brass and Copper Pipe" was then presented. Mr. W. K. Tavel, representing the Chase Brass and Copper Company, Waterbury, Conn., gave brief talks during the showing of the picture.

A paper and slides on "Pollution Hazards of Ground Water Supplies" was presented by Geo. A. Johnson of Wallace and Tiernan Company.

Mr. Forsberg announced from the chair the recent death of Wm. Todd, Superintendent of Water and Light, Austin, Minn. Mr. Todd was 74 years old at the time of his death, had been with the association for 25 years and was a life member, and for 41 years had been Superintendent of the Austin Water and Light Department. Mr. John Druar offered the following resolution, that a letter of condolence be sent to the immediate family and that the secretary write the National Secretary instructing them to carry this notice in the next issue of their JOURNAL.

At this point the meeting stood adjourned until 6:30 P.M. Chairman Forsberg announced that the banquet would be held in the Grand Ball Room and requested that all be there at the appointed hour.

The local committee certainly left nothing to be desired when they arranged for the entertainment. The speaker for the evening, Dr. W. A. O'Brien of the University Hospital, gave an interesting and educational talk on "Health Education."

The meeting adjourned at 9:30 P.M.

R. M. FINCH,
Secretary and Treasurer.

THE CENTRAL STATES SECTION

On October 8 and 9, 1931, the Central States Section met for its Thirty-Third Annual Convention at Cincinnati, Ohio, with headquarters at the Hotel Netherlands Plaza.

While the attendance this year was below normal, the Convention was otherwise one of the most successful this body ever had.

The program shown below was carried out as outlined. The papers were practical and well received. The round table discussions on Friday were particularly interesting and discussed freely.

The offices and Trustees of the Section for the next year are as follows: Chairman, Albert S. Hibbs, Superintendent, Department of Water Works, Cincinnati, Ohio; Vice-Chairman, George Whysall, Manager, Marion Water Company, Marion, Ohio; Secretary-Treasurer, B. J. Lechner, Secretary-Treasurer, Commissioners of

Water Works, Erie, Penna.; Trustees, D. C. Grobbel, Secretary, Board of Water Commissioners, Detroit, Mich., George M. Keefer, Pittsburgh, Penna., Wallace W. Morehouse, Director, Department of Water, Dayton, Ohio; American Water Works Association, Director, J. S. Dunwoody, Superintendent, Commissioners of Water Works, Erie, Penna.

Erie, Pennsylvania, has been chosen as the meeting place for the 1932 Convention, with head quarters at the Hotel Lawrence. The exact date, late in September, has been left to the decision of the officers.

THURSDAY, OCTOBER 8

MORNING SESSION

Address of Welcome, John D. Ellis, City Solicitor, Cincinnati.

"Trunk Main Surveys by Means of the Pitometer," Edgar K. Wilson, Chief Engineer of The Pitometer Company.

"The Use of Activated Carbon for the Removal of Tastes and Odors," F. H. Waring, Chief Engineer, Department of Health, Columbus, O.

Business and Announcements. Election of Association Director for 1932.

AFTERNOON SESSION

"Stub Plan of Customers Accounting for Water Works," M. F. Hoffmann, Assistant Superintendent, Commercial Division, Cincinnati.

"A Preliminary Draft of Revised Specifications for Gate Valves," Wm. R. Conard, Chairman Sub-Committee No. 7-E of the Water Works Practice Committee on Gate Valves and Fire Hydrants.

General Discussion.

"Larval Contamination of a Clear Water Reservoir," Clarence Bahlman, Water Purification Supervisor, Cincinnati Filtration Plant.

Election of Officers. Selection of Place for 1932 Meeting.

EVENING

Dinner at Hotel Netherland-Plaza

Address by Hon. Charles P. Taft 2nd, "Municipal Government by the Charter and City Manager Plan."

FRIDAY, OCTOBER 9

MORNING SESSION

Open Forum Discussion of Practical Questions of Water Works Operation and Maintenance

Meeting in charge of J. S. Dunwoody, General Superintendent, Water Works, Erie, Pa.

Partial list of questions:

1. False reports on sickness caused by city water.
2. Trouble with coating on Delavaud pipe.
3. Breakage of fire hydrants in the winter due to frost.

Open Forum Discussion of Practical Questions of Water Purification

Meeting in charge of Clarence Bahlman, Water Purification Supervisor,
Cincinnati, Ohio

Those in attendance are invited to introduce other topics.

1. Is there a noticeable progressive change in the quality of water and the type of bacteria in city water supplied from year to year?
2. Is there a satisfactory water-proofing material on the market for rendering concrete impervious to water pressures of 5 to 10 pounds per square inch?
3. What type of coating is best adapted to protect metal surfaces against corrosion?
4. How effectively can dirty filter sand be washed by sand ejectors or a Nichols sand washer?
5. What success have you had in washing and regrading sand and gravel from filters long in use?

AFTERNOON

Inspection trip

Eden Park, Victory Parkway, Ault Park, Lunken Airport, California Filtration Plant (the first large rapid sand filtration plant in the United States, constructed 1907, capacity 140 m.g.d.), River Pumping Station with the highest triple expansion pumping engines in the world, returning via new Columbia Ave. development; visiting the Main Pumping Station.

B. J. LECHNER,

Secretary-Treasurer.

ABSTRACTS OF WATER WORKS LITERATURE¹

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Developments in Water Purification Practice. PAUL HANSEN. Eng. News-Rec., 104: 839-43, 1930. Review and discussion, including sedimentation, coagulation, chemical feed, filtration, and chlorination. Owing to difficulties from filter sand incrustation with lime and iron coagulation, alum found general preference as a coagulant. Since development of carbonation, lime and iron coagulation is increasing in popularity, owing to difficulty of obtaining good flocculation of alum with unfavorable temperature or pH. The heavier $\text{Fe}(\text{OH})_3$ is also more effective in carrying down microorganisms. Sodium aluminate is effective, but expensive, its cost outweighing its advantages. Chlorinated copperas has been found effective and economical at several places. Importance of agitation is becoming more appreciated, tendency being to employ mechanical stirring devices and longer periods of mixing. At Highland Park, Mich., mixing period of 50 minutes has been provided for. Trend is also to employ longer settling periods following addition of coagulant, periods of less than 2 hours being rare, 6 hours not uncommon, and up to 18 hours having been found advantageous. Introduction of artificial turbidity has been found effective in promoting flocculation in waters naturally clear. At Winnetka, Ill., ground brick clay is applied through dry-feed machine. Apart from tendency to employ higher rates of backwash, there has been no significant modification in design, or operation, of rapid sand filters. For a number of years molded concrete underdrains were favored, but pipe systems are now almost universal. In recent years there has been a tendency to employ coarser sand, i.e., effective size of 0.55 mm., rather than the 0.35 mm. standard of a few years ago. Pressure filters are practically obsolete in municipal practice. —R. E. Thompson (*Courtesy Chem. Abst.*).

Pumping Seepage Water from Wells for Irrigation. E. H. NEAL. Eng. News-Rec., 104: 1020, June 19, 1930. In Boise River valley, in southeastern Idaho, an experiment is being made on pumping excess underground water to surface at points where it can be utilized for irrigation, thus also relieving the

¹ Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

wet land, the continual application of water to the higher areas having overtaxed the natural and artificial drainage.—*R. E. Thompson.*

Alternate Stages and Critical Depth in Circular Hydraulic Conduits. THOMAS R. CAMP. *Eng. News-Rec.*, 104: 1016-7, 1930. Formulas and diagrams are given for determining alternate stages and critical depths for any discharge and for any size conduit within the usual ranges.—*R. E. Thompson (Courtesy Chem. Abst.).*

Sand-Clogged Outfall Sewer Cleaned and Joints Calked. L. R. WALKER. *Eng. News-Rec.*, 104: 905-6, May 29, 1930. Leakage from outfall sewer at Santa Barbara, Cal., resulting in serious beach pollution, recently necessitated extensive repair work. Investigation showed that settlement had opened the joints between sections of the concrete pipe, and leakage was aggravated by sewer being partially blocked with sand, which resulted from draining of low land in 1927-8. The outfall was placed in commission in 1926 and consists of 3700 feet of 42-inch concrete pipe, in 12-foot lengths, discharging about 3200 feet from shore in 45 feet of water. Joints of first section of line were made with asphaltic compounds, an improved joint of loose oakum rope coated with asphaltic material being later developed. Repair work was carried out from barge by divers. Sand was removed with 4-inch suction hose through man-holes located every 300 feet excepting the first one off shore which is 400 feet from beach manhole. Where sand was too compacted to yield to suction it was agitated by jet from separate hose line. All of old asphaltic filler was removed and the 260 joints were calked with lead wool with aid of air hammers. Collars were cast around the pipe at two joints which had opened too far to be repaired by calking. Working time for contract work was 118 days and contractor used 13,575 pounds of wool. Contract price was \$39,279.—*R. E. Thompson.*

Abnormal Dry Season in Far West in 1929. EDWARD H. BOWIE. *Eng. News-Rec.*, 104: 1020, June 19, 1930. Brief data. At 10 of 21 stations the 1929 precipitation from July to December was below the minimum for all previous years on record (31 to 80 years).—*R. E. Thompson.*

Distribution System Practices of a Large Group of Water Companies. GEO. W. BIGGS, JR. *Eng. News-Rec.*, 104: 851-5, May 22, 1930. Distribution system of average water plant, including mains, services, meters, valves and hydrants, comprises approximately 60 percent of total investment. Average cost of operation and maintenance of distribution system represents about 8 percent of the total operating expenses, including depreciation and taxes. Pipe breaks usually result from a combination of stresses from hydraulic pressure on interior surface with transverse stresses due to uneven bearing of pipe on bottom of trench, or to settlement. Average unaccounted for water for the 42 water works owned and operated by the American Water Works and Electric Company was 23 percent for 1929. The lowest for any one plant was 2.1 percent, 90 percent of water pumped being used by 3 industrial consumers close to plant. Leakage surveys are made when unaccounted for water appears too

high. In some of larger plants, permanent pitometer connections have been set in main feeders. With substitution of bus lines for electric railways, damage to mains by electrolysis is becoming less. Installation of return feeders paralleling the rails and proper binding of the rails will reduce electrolysis to minimum. Tuberculation can be greatly reduced by entirely removing carbon dioxide. This is of particular importance after cleaning of mains. Cement-lined cast iron pipe has been the standard of the subsidiary plants of above company for past 5 years, tuberculation being effectively eliminated thereby. The only deterioration of cement lining has been a slight leaching of lime from the surface. Pipe as small as 2-inch is lined with cement. Use of wyes in pressure lines should be avoided, as standard design of wye does not provide sufficient strength to take care of the large opening at junction of branch and fitting. It has been found that use of lead substitutes on tapping sleeves results in frequent breaking of the sleeves. It has also been found advisable to use lead instead of substitutes where hydrant branches are joined to hydrant hubs and for mains under railroad and street-car tracks. Proper installation of mains under tracks at greater depth than pipe is ordinarily laid will reduce maintenance costs. It is difficult to distinguish between charges to maintenance and replacement reserve. A general rule has been established by the Company to charge depreciation reserve with original cost of unit of property when replaced, and maintenance expense with cost of maintaining unit in serviceable condition during period of its existence. Replacement of more than one length of pipe, of a fitting or special, of a valve or valve box, is charged against depreciation reserve, all other expenses being charged to maintenance or operation. Choice as between lead and copper for services depends on first cost, as there is little difference between their durability and maintenance costs. Their use has reduced maintenance and replacement. Maintenance of meters in a fully metered system is one of largest items of distribution expense. Use of breakable cast iron frost bottoms keeps cost of repairing frozen meters to minimum. Advantages of placing meters at curbs far outweigh the disadvantages. Each valve in system should be operated at definite intervals and fire hydrants should be inspected at least once, and preferably twice, each year. In addition to this, practice of the Company is to operate and inspect fire hydrants after use by fire department. If properly installed, distribution system is practically permanent, involving a minimum of expense for maintenance and renewals.—*R. E. Thompson.*

Steam Averts Freezing of Water Mains at Leadville, Colo. Eng. News-Rec., 104: 888, May 29, 1930. Water mains at Leadville are laid 6 feet below surface, which is sufficient to protect them under most conditions. During winter of 1928-9, however, when snow blanket was light and weather severe, heroic measures were required to prevent freezing. Steam boiler at pumping station was connected to one 8-inch city main and steam forced in until the temperature of water was raised above danger point. Use of a second boiler was loaned to city for same purpose. Last year 2 additional boilers were added to pumping station equipment to deliver steam to mains when necessary. Steam is injected until water temperature reaches 40°F., the procedure being repeated as required.—*R. E. Thompson.*

Costs of a Water Distribution System. MAX VAN DE GREN. *Eng. News-Rec.*, 104: 868, May 22, 1930. Unit costs of water distribution system comprising nearly 54 miles of 6- to 24-inch pipe, built by village of Roseville, Mich., in 1928-9, are tabulated. The 24-inch pipe is a feed main from Detroit water works. Regular terms of city of Detroit to outside communities were enforced. All plans are to be approved by Detroit Water Board. Size and location of pipes are to follow master plan of Detroit metropolitan area and valves and hydrants must be of city standard. Village is to provide foundry inspection of pipe and pay city for inspection of pipe laying at 3.5 cents per foot. All services are to be metered. Title to all mains larger than 8 inches is to be given to city. Village is to form water board to operate system and city is to be paid for all water supplied, at present passing through a single meter, at double the rates charged in Detroit. A contract including all these conditions was approved by popular vote, as was also a \$350,000 construction bond issue, based on assumption that part of cost of works would be assessed upon property benefited at rate of 87.5 cents per foot frontage. Later, assessment was fixed at 40 cents and \$450,000 of additional bonds were authorized.—R. E. Thompson.

Electric Sluice Valves. *Cont. Rec. and Eng. Rev.*, 44: 641-2, May 28, 1930. Brief description of 2 large, self-contained, electrically operated sluice valves designed for remote control recently supplied to city of Ottawa, Ontario. These units are 60 inches in diameter, working under head of 34 feet. Hand operation can be resorted to in case of power failure. Bodies are of finest gray cast iron, with very smooth finish. Heavy gunmetal faces are fitted to valve body and door, securely attached by screwed brass pins, and hand scraped to form a perfectly watertight joint. Operating screws, accurately machined from forging of high tensile manganese bronze, work in gunmetal nut secured to valve door. Worm reduction gear is housed in totally enclosed cast iron casing containing oil bath. Lubricators are provided for all headstock bearings, and ball thrust washers fitted to each end of worm shafts are packed with grease.—R. E. Thompson.

Submerged Water Main of 8-Inch Reinforced-Rubber Pipe. WALTER C. MUNROE. *Eng. News-Rec.*, 104: 855-6, May 22, 1930. During summer of 1928 a serious outbreak of typhoid fever occurred in Eastport, Md. State department of health assumed immediate charge and promptly arranged with Anne Arundel County Sanitary Commission for construction of water distribution system to serve some 500 dwellings in village. At that time individual wells were in use, these being unquestionably responsible for rapid spread of disease. Nearest source of supply lay in city of Annapolis, separated from area affected by Spa Creek, a body of salt water spanned by highway bridge 590 feet long with swing draw 115 feet wide near center of stream. Investigation showed average depth of 11 feet, with bottom of ooze and muck to depth of some 40 feet. A 12-inch main was laid upon beams fastened to the bridge members from either shore to the drawspan. Rubber pipe was decided upon for the submerged connecting section across the drawspan, in view of unsatisfactory bottom conditions and somewhat tortuous path of 150 feet necessi-

tated by certain obstructions. The rubber pipe is 8 inches in diameter, the $1\frac{1}{2}$ inches thick walls being reinforced with 0.283-inch diameter copperized-steel wire wound spirally at $\frac{1}{4}$ -inch spacing and embedded about $\frac{1}{4}$ inch from outer surface. The pipe was manufactured in three 50-foot lengths and fitted with standard cast iron flanged couplings, the flanges being cast integral with beaded nipples, which were built into the pipe. As an extra precaution, heavy navy bronze clamps were fastened over the nipples and made up tight before installing. The three sections were jointed on shore and the couplings covered with special waterproofing material applied hot over a coating of priming, connection to shore sections being made by means of 8-inch vertical drop pipes. A water jet was used to sink pipe in the soft bottom. Cost of under-water installation, including all materials and removal of old bridge timbers and debris, was \$1250. The entire line, or half of it, can be raised at any time for inspection by disconnecting and pumping air into it.—*R. E. Thompson.*

What Experimental and Research Work has Accomplished in Water Purification. NORMAN J. HOWARD. *Cont. Rec. and Eng. Rev.*, 44: 640-1, 1930. Brief discussion of developments in water purification, with particular reference to rôle played by research.—*R. E. Thompson (Courtesy Chem. Abst.).*

Liability for Impure Water. *Eng. News-Rec.*, 104: 19, July 3, 1930. Attorney General WARD of State of New York has rendered an opinion regarding liability of private water companies and of municipalities when water has been found unsafe for human consumption. The opinion, in part, is as follows: A water company, or municipality furnishing water, is not a guarantor of the purity of its product in absence of a contract obligation to that effect and is not responsible to a party poisoned by impurities in the water unless shown to have known of the condition of the water, or to have been negligent in failing to discover, or disclose, the danger; nor is it responsible in any case where the party injured was himself at fault; still, such company or municipality must furnish pure and wholesome water fit for domestic use, but not necessarily chemically pure. If the water does not conform to this standard, such company or municipality may be liable for damages to persons injured by reason of the impurities. Posting of notices to effect that water is unfit for drinking purposes does not absolve municipality, or water company, from using diligent effort to render said water pure and wholesome and, if a water company or municipality should fail so to do, the water company, or municipality, is liable in damages to a person injured by reason thereof, and the mere posting of such notices will not relieve the company, or municipality, from its liability.—*R. E. Thompson.*

Relative Values in Five Classes of Utility Systems. C. F. LAMBERT. *Eng. News-Rec.*, 104: 1058, June 26, 1930. This article brings up to date of January 1, 1930, records of comparative values of the 5 groups of public utilities, values in 1913 being taken as 100 percent, as given annually in *Engineering News-Record*. The data for water works are based on 25 systems in various parts of the United States.—*R. E. Thompson.*

Water Works Intakes of the Middle West. CHARLES B. BURDICK. Eng. News-Rec., 104: 834-8, May 22, 1930. Discussion of the various types of intakes required under the different conditions met with in practice, examples of each type being described and illustrated. Intake of the Lexington Water Company is illustrated as typical impounding reservoir intake, with provision for drawing water from different levels. Sand on lake bottoms travels more or less during storms at depths of less than 20 feet and it is therefore desirable to draw water from a plane 4 to 8 feet above the lake bottom. Owing to danger of ice, which in severe weather piles up in windows as high as 10 feet above lake level and fills shallow water almost solidly to the bottom and extending as far as 500 to 1000 feet from shore, it is desirable to locate lake intakes in depths of not less than 20 feet, preferably of 30 or 40 feet. One of the Chicago intakes is described as an example of a surface intake crib. The crib is 110 feet in diameter and is built of heavy stone masonry and concrete, located in 32 feet of water, 2 miles from shore. Water is admitted from eight 7-by 7-foot ports into large interior well, from center of which a vertical shaft extends downward into tunnel. The heavy masonry shell extends up to level of maximum wave influence and is surmounted by lighthouse. Living quarters are provided for lighthouse keeper and for extra help periodically required to fight anchor ice, facilities for steam generation for use when anchor ice is prevalent being also included. At Gary, Indiana, a submerged intake crib has been in use with gradual increase in pumpage for 20 years, no stoppage with anchor ice having occurred in that period. It is located in 44 feet of water and projects 11.5 feet above lake bottom. Crib proper is a 60-feet octagon, closed on top, water being admitted through 12 ports in top cover, each 5 by 5½ feet. The water passes to the center and downward through 10-foot shaft to 6-foot tunnel leading to pumping station on shore. Maximum port velocity to date has been only 0.14 foot per second. During critical ice periods, velocities have been much less than this figure. A similar submerged intake crib has been in use at Racine, Wis., for about 2 years. As at Gary, the ports, which are not provided with screens, are in the top, or cover, of the crib on a horizontal plane 8 feet above lake bottom and are designed for maximum port velocities of about 0.25 feet per second. The timber crib structure, which is surrounded with loose rock for stability, is 33 feet 4 inches square, with the ports at the outer edges. For smaller towns, the desirable features of the above intakes—moderate port velocities and distribution of draft—can be secured with less expensive structures. At Glencoe, large port area and decentralization of intake is secured by dividing the 24-inch cast iron intake pipe into 3 branches, the intake draft being thus distributed over a 20-by 65-foot area. The intake ports are 3300 feet from shore and lie in a plane 4 feet above lake bottom, submerged about 19 feet at low water. Structures such as that at Knoxville, Tennessee, have been successfully used for intakes in rivers with stable bottoms. The Knoxville intake consists of two 36-inch pipes carried on piers about 4 feet above river bottom. Each pipe is perforated with 1-inch holes on 2-inch centers, and is capped at the end with a perforated plate. The pipes extend 60 feet from shore, the minimum water depth being 11 feet. It was necessary to go 700 feet upstream from the pumping station to find suitable conditions. A similar intake has been in use at Evansville, Indiana, for 30

years. The New Albany intake is located near the foot of the Ohio rapids, 100 feet from shore, in water about 3 feet deep at low water. The 24-inch intake pipe was laid in a trench excavated in rock. The intake box is built of steel plate, the inlet port, which has an area about 5 times that of the pipe and faces downstream, being protected by a bar screen. The intake pipe and box of the Terre Haute Water Company, which is located at a bend of the Wabash River where the bottom is unstable, is supported on piles. The intake built for Laredo, Texas, illustrates a method frequently employed for river intakes on eroding bottoms. It consists essentially of a suction box or well located at the water's edge and of sufficient height to be accessible from the shore under ordinary high-water conditions. Water is admitted through either of 2 sluice gates in the side of the well. Sliding screens, accessible from the top of the structure, intervene between the gates and the pump suction.—*R. E. Thompson.*

Engineering Conditions in Hawaii. H. E. BABBITT. *Eng. News-Rec.*, 104: 976-9, 1930. The water supply of Honolulu is obtained from artesian wells 600 feet deep. The level to which the artesian water rises has dropped from 42 feet above sea level in 1888 to 28 feet at the present time (23.5 feet in 1926) and, as the minimum safe artesian pressure to prevent sea water being admitted is 22 feet, plans have been prepared for a supplementary surface supply.—*R. E. Thompson (Courtesy Chem. Abst.).*

A World Wide Challenge. LEE ROWLAND. *Eng. News-Rec.*, 104: 943, June 5, 1930. A flow of 8.25 million gallons per day from a 12½-inch artesian well 780 feet deep at Roswell, N. M., is reported.—*R. E. Thompson.*

Inclosed Masonry Standpipe at Lawrence, Mass. MORRIS KNOWLES. *Eng. News-Rec.*, 105: 70, July 10, 1930. Brief illustrated description of standpipe built at Lawrence, Mass., in 1895-6. The masonry tower, built of brick and stone, is octagonal. Outside diameter of the steel standpipe is 30 feet 1½ inches. Thickness of masonry walls tapers from 24 inches to 16 at level of balcony floor, above which thickness is only 1 foot. A spiral stairway is contained within the masonry tower. Total height above ground is 157 feet, steel standpipe being 107 feet high. Cost was \$40,419, of which \$18,187 was for standpipe and \$21,719 for masonry tower.—*R. E. Thompson.*

Elevated Tank Over Old Standpipe. *Contract Record and Eng. Rev.*, 44: 795, June 25, 1930. Brief illustrated description of 600,000-gallon elevated steel tank recently erected around an old standpipe in Toronto, Ont. Standpipe was 20 feet in diameter and 100 feet high, and had been in service approximately 20 years. New tank has diameter of 45 feet and shell height of 45.5 feet. Top of tank is 105 feet above foundations, allowing a 5-foot free board over the original standpipe which was not removed.—*R. E. Thompson.*

Unusual Elevated Water Tank at Hertford, England. *Eng. News-Rec.*, 104: 967, June 12, 1930. Brief illustrated description of reinforced-concrete water

tank, of 240,000 U. S. gallons capacity, recently completed at Hertford. A concentric partition wall divides tank into 2 approximately equal parts. Floor of tank is 75 feet above ground water level and is supported by 8 columns and large central access shaft. Latter is octagonal in plan, 17 feet 10 inches across, and contains pipe connections and stairway. A continuation upwards of access shaft, 6 feet 3 inches square, is covered by cupola, toward which tank roof slopes somewhat. Tank floor has thickness of $5\frac{1}{2}$ inches and walls a minimum of 4 inches. Pumping and delivery mains are 10 inches in diameter, branching in access shaft to connect with each compartment. Cost was upwards of £7,000.—*R. E. Thompson.*

Tank Faced with Stone and Brick. Eng. News-Rec., 104: 863, May 22, 1930. Attractive appearance has been given water tower recently constructed in fine residential neighborhood in St. Paul, Minn., by enclosing tank and pumping plant in hexagonal tower of reinforced concrete faced with brick and stone. Tank, which has capacity of 200,000 gallons, is located immediately adjacent to an 18-million gallon reservoir in Highland Park. Tower is 127 feet high and consists of 4 floors. Basement houses the pumping equipment, 2 motor-driven centrifugal pumps with capacity of 500 gallons per minute. Main floor is a large open room. Tank itself, 24 feet in diameter and 60 feet high, is supported on a floor 25 feet above main floor. A spiral stairway between tank and outside wall leads to the top or observation floor. The upper 20 feet is illuminated by floodlights. Total cost was \$71,500, of which about \$20,000 was for tank and pumps. A plain tower would have cost about \$20,000. Additional cost of the finer materials and architectural treatment, therefore, was \$31,500.—*R. E. Thompson.*

Standpipes and Water Towers. R. L. SACKETT. Eng. News-Rec., 104: 780, May 8, 1930. Brief description of water tower built at Eastern Hospital for the Insane, Richmond, Indiana, in 1901-2. Tower, which conforms in architecture with other buildings of the institution, is 20 feet in internal diameter and 110 feet high, with walls of reinforced concrete 4 inches thick at top and 12 inches at base, faced with brick. The steel standpipe is entirely separate from exterior wall, which was built for the sake of appearance and of more equable water temperatures. Approximate cost figures are: standpipe, \$4,000; foundations, piping and valves, \$1,500; shell, \$3,500; total, \$9,000.—*R. E. Thompson.*

6,000,000-Gallon Steel Reservoir Near Rochester Completed. Eng. News-Rec., 104: 948, June 5, 1930. New 6-million-gallon steel reservoir of Rochester and Lake Ontario Water Service Corporation at Cobb's Hill is said to be largest steel reservoir in America and the only one with welded steel plate bottom. The tank is 200 feet in diameter and consists of 4 rings of 26-foot by 6 $\frac{1}{2}$ -foot steel plates. Plates of lowest ring are 1 inch thick.—*R. E. Thompson.*

Suits for Waterborne Typhoid Compromised by Company. Eng. News-Rec., 104: 910, May 29, 1930. Typhoid claims against Texas-Louisiana Power and

Light Company, resulting from epidemic at Richfield Springs, Texas, in autumn of 1929, have been compromised for \$15,000, following court action. Twenty-eight cases of fever "variously diagnosed" were reported to Texas State Board of Health. Only one death occurred. Dependents of deceased will be paid \$5000 and remaining \$10,000 will be distributed for benefit of survivors and their relations. Complainants alleged that local water supply was contaminated through carelessness of company. The springs forming source of supply were "possibly infected by septic tank drainage, or by surface drainage from open privies." Estimated population of Richfield Springs is 800.—*R. E. Thompson.*

Meter Installation and Operation Practice. H. P. MATTE. *Eng. News-Rec.*, 104: 857-9, May 22, 1930. About 30 years ago average of only 25 percent of services in group of 100 of larger cities in America were metered, while to-day average of at least 80 percent of services in these cities would be metered. Accurate records are not available, but it would seem that at least 65 percent of population on public water works systems in United States is, in cities at least, 70 percent metered. Data are given on development and standardization of water meters. In general, the original types of meter are still employed. Tendency is strong toward universal adoption of the standard specifications adopted by water works associations in coöperation with manufacturers. While great majority of water works purchase and own their meters, about 20 percent of them require consumer ownership, although in most cases meter is purchased by city. In the country as a whole, present trend is toward municipal ownership of meters. General practice is for maintenance of meters to be carried out by municipalities or water works, requiring consumer to pay for repairs rendered necessary by heat, frost, and violence. It has gradually become the custom for all large and nearly all medium-size cities to test meters before they are accepted for setting. The tests vary in severity, although most water works have adopted, either in whole or in part, the specifications of the water works associations. Practice of setting meters varies. In many cities plumbers or contractors install them, but trend is toward setting of meters by water department or company. In any case, meters are inspected and sealed by water works employees. For country as whole, preference is about evenly divided between setting meters in basements and in curb boxes. There is wide divergence of opinion as to justifiableness of expense of periodical testing and overhauling. Balance of opinion apparently leans toward conclusion that saving does not warrant the expense, owing to fact that cost of removing, testing, and replacing meter is greater than resulting benefits. Some states require testing of meters at stated intervals, or after passage of a certain quantity of water. The time of service prescribed varies between 5 and 10 years. Such rules generally apply to water companies only. A few municipalities have adopted definite schedules, but great majority of water departments remove and test meters only when they stop, or obviously slow up, or upon request of consumer. Quarterly readings of domestic meters lead over monthly readings by 3 to 1. Both card system and stub system of billing are in use, although practice of eliminating all but the meter readers books and using the stub, or duplicate bill, as a record is gaining headway.—*R. E. Thompson.*

Selective Metering Considered Economical in St. Louis. Eng. News-Rec., 104: 860-1, May 22, 1930. Selective metering, i.e., installing meters on only those services whose owners use a very large amount of water and in those districts where water waste is excessive, is considered to be the most economical method of eliminating wasteful consumption in St. Louis. During year ended April 1, 1929, consumption averaged 118.4 million gallons per day, or 129 gallons per capita, based upon estimated population of 918,000. Services in use total nearly 145,000, ranging in size from $\frac{1}{8}$ -inch to 12-inch, about 7.7 percent being metered. All industrial consumers and other large users are metered. Of income from water sales, 43.1 percent is from metered consumers. Deducting that used by industry and the small amount lost through pipe line leakage, net consumption is 80 million gallons per day, or 87 gallons per capita. If waste items were eliminated entirely, domestic consumption would be reduced to 67 million gallons per day, or about 73 gallons per capita. Total wasteful consumption under direct control of the householder, 13 million gallons per day, is made up of 7 million gallons household waste, including that due to defective plumbing, and 6 million gallons caused by allowing faucets to run continuously during freezing weather. It is improbable that metering would have any marked effect on latter type of waste. Data are given showing that waste is not distributed evenly throughout city. Metering water delivered to only 19.5 percent of population would result in elimination of 50.5 percent of total household waste, while installation of meters in another district would save only 8.9 percent of waste, although representing 38.6 percent of population. About 30 inspectors are employed in maintaining reasonable rate of consumption through unmetered services. During year ended April 1, 1930, total of almost 185,000 inspections disclosed 18,836 leaky fixtures.—*R. E. Thompson.*

Piecework Pay for Meter Readers. E. R. HOLLOWAY. Eng. News-Rec., 104: 867, May 22, 1930. Flint, Michigan, is divided into 3 sections for meter reading and billing. Accounts which average under \$10 per month are read and billed quarterly; those averaging over \$10 per month are billed monthly. Reading and billing are continuous and work is equally distributed throughout the month. Two employees read all meters which are billed quarterly, about 30,400 in number. Readings are paid for at rate of \$3 per 100: previous readings are not supplied to readers and readings found to be incorrect are not paid for. Readings are posted in books of department and carefully compared with previous readings. Any abnormal variation is checked by extra reader, also used as follow-up man for readings not obtained due to absence of occupants. This man also takes readings for monthly billings and makes other special investigations.—*R. E. Thompson.*

Research into the Properties of the Aërobe, the Non-sporulating Lactose-Fermenting Bacteria in Feces and Soil in the Tropics and the Importance thereof for the Analysis of Drinking Water. K. HOLWERDA. Meded. Dienst. d. Volksgezondheid in Nederl.-Indië, 1930, 19: 289-324. From Bulletin of Hygiene, 6: 4, 357-8, April, 1931. Of 674 strains of coliform lactose-fermenting bacilli isolated from feces, 96.3 percent were typical *B. coli* as determined by

the Voges-Proskauer, methyl red, and citrate tests. Two-tenths percent were intermediates and 3.5 percent were typical members of the aerogenes group. Of 277 strains of coliform bacilli isolated from soil samples, taken at depths of one meter or more below the surface, 77.1 percent were of the aerogenes group, 18.9 percent intermediates, and 4 percent typical *B. coli*. One hundred and seven strains isolated from surface soil in uninhabited regions gave 31.8 percent typical members of the aerogenes group, 29 percent intermediates, and 39.2 percent typical *B. coli*. Conclusion is that if coliform lactose-fermenting bacilli isolated from a water sample are found to belong exclusively to aerogenes group or to intermediate group, the evidence is against recent fecal pollution.—Arthur P. Miller.

The Purification of Phenolic Wastes. W. A. UGLOW. *Ztschr. f. Hyg. u. Infektionskr.*, 1930, 111: 511-30. From *Bulletin of Hygiene*, 6: 4, 359, April, 1931. Experiments indicate that activated sludge possesses the power of destroying certain phenolic substances and that, conversely, the efficiency of activated sludge may be increased by these chemicals. Phenol in concentration of 1 in 550 can thus be destroyed. Best results can be obtained in the activated sludge scheme if preliminary filtration of the trade waste is made through a bed of coal. The resulting effluent gives negative chemical tests for phenols and will support fish life if the liquid is kept aerated.—Arthur P. Miller.

Cook County Provides Safe Swimming. CHARLES G. SAUERS. *American City*, 44: 1, 139-140, January, 1931. Insistence of visitors to Cook County, Illinois, Forest Preserve District upon swimming in polluted natural streams therein led to construction of fine new swimming pool in area where pollution is worst. Pool is 100 by 250 feet, with usual accessories, and of recirculation type. Basket method of handling patrons' clothes is used. Fact that no serious accident has occurred from falls during season past is considered amply to justify non-slip floors provided. Nude bath is enjoined on all bathers and rigid inspection excludes those with harmful physical deficiencies. Sterilizers, hair-strainers, pressure filters, and suction cleaner are included in equipment. A set of sprays capable of producing a "mill race" effect or of spraying the water in thin sheets, is a novel feature. Capacity of purification system is one complete turnover every eight hours.—Arthur P. Miller.

Bronze-Welding of Cast Iron Pipe. Anon. *The American City*, 44: 1, 141-144, January, 1931. Describes in detail welding technique and organization necessary for bronze-welding of cast iron pipe. Precautions to be observed are set forth and some examples given of recent practice.—Arthur P. Miller.

Construction of the New Otay-San Diego Water Line. Anon. *The American City*, 44: 2, 139-140, February, 1931. San Diego, California, has recently completed third major improvement in its water supply system since 1914. This consisted of installation of new transmission line from Otay reservoir to the city, a distance of 19 miles. New pipe-line is of steel, arc-welded, and replaces wood-stave line which has been in service since 1901. Old line had capacity of 10 m.g.d., while new one will carry 17 m.g.d. and, when booster

pumps are put in, 25 m.g.d. Four large tunnels, longest of which was 2150 feet, were necessary. The whole line, excepting tunnel sections, was dipped in hot asphaltum and wrapped with special felted fabric. All joints were welded both inside and out. This process has been found very satisfactory. Test of ten-mile section showed only one major leak.—*Arthur P. Miller.*

Put "Drawdown" in Your Specifications for Water Wells. HOWARD O. WILLIAMS. *The American City*, 44: 134-135, February, 1931. In preparing fair well specifications, aim should be to include such provisions that completed job will satisfy sanitary requirements, that contractor will be allowed considerable leeway for using his own judgment, and that procurement of required quantity of water as cheaply, dependably, and permanently as possible will be insured. Almost all specifications for wells fail to mention drawdown. This factor is as important to a well as the head is to a pump insofar as specifications are concerned. Writer suggests that there should be included a provision to effect that well shall deliver a certain quantity of water with drawdown not to exceed a certain figure at end of pumping test and that there shall be a bonus, or a penalty, as the case may be, for exceeding, or falling short of the set figure. Formula for computing such lump sum bonus per foot is given.—*Arthur P. Miller.*

With New Source of Water Supply, Town Buys Its Distribution System. F. M. VAN VOORHEES and G. M. HUTTENLOCH. *The American City*, 44: 2, 95-96, February, 1931. Montclair, New Jersey, was served with water for years by Montclair Water Company subsidiary of Passaic Consolidated Water Company. Source was Passaic River at Little Falls, where also it was filtered. As citizens were not satisfied with this supply, town arranged to purchase its distribution system, became partner in Wanaque project, then under construction, and purchased from Newark a temporary supply. On July 17, 1930, Wanaque water was turned into Montclair mains. In order to improve pressure and storage facilities, two new reservoirs have been erected on Watchung Mountains. Pressure of new supply is now 35 pounds at elevation 220. Two new pumping stations were built, town was re-zoned into two pressure areas, and many improvements made in distribution system. Montclair can face next two decades without apprehension of water shortage.—*Arthur P. Miller.*

The Municipal Power Plant and Water Works in a Town of 3,500. BENNETT B. SMITH. *The American City*, 44: 3, 97-98, March, 1931. In 1904 Cameron, Missouri, town of 3500 people, took first step to procure water works system. Original system came about as result of disastrous fire and was intended only for fire protection and for watering lawns and gardens. In 1909 a crude filter plant was added which worked with indifferent success. However, from that time on gradual improvements in methods of adding chemicals have taken place, personnel has improved, and control of plant has become quite satisfactory, being rated A by State health authorities. Laboratory is now not only testing its own water, but is also serving the surrounding community. Equipment has been added as required, until quality of water has become satisfactory. Municipal power plant is also described.—*Arthur P. Miller.*

Booster Station and Water-Main Cleaning Solve a Supply Problem at Columbus, Ohio. Anon. *The American City*, 44: 3, 103-104, March, 1931. During last few years, Hilltop section of Columbus, Ohio, has enjoyed such rapid growth that water supply system has not kept pace with it. After careful investigation, booster station was installed on main serving this district. This brief article describes acceptance tests of equipment installed. In July, 1930, consumption of water was from 125 to 150 per cent above average and, even with booster station, peak demands could not be met. Contracts were therefore let at different times for cleaning about 27,000 feet of large main close to booster station in order to regain excessive loss of pressure. Marked improvement in delivery capacity throughout this high district resulted. Reduction of carrying capacity of pipes was caused by deposits of insoluble calcium carbonate which had accumulated during 20-year period of lime-soda water softening.—*Arthur P. Miller.*

County-Seat Improves Pressure in Distribution System. Anon. *American City*, 44: 3, 133, March, 1931. Water supply of Van Wert, Ohio, with population of about 8,500, is obtained from four deep wells. Additional storage was required in 1929 and second elevated tank was erected. Overflow elevation of new tank required study to adjust it so that maximum use could be had of both new and old tanks. Calculation was rendered difficult because of cross-connection in gridiron fashion of distribution system and because the way that service connections were taken off at various points made quantity flowing at any given point uncertain. However, certain assumptions were made and elevation calculated. Although tanks were over a mile apart, after they were in operation calculated elevation for overflow of new tank was only three inches above high water line.—*Arthur P. Miller.*

New 80-Foot-Diameter Steel Water Tank for Cedartown, Georgia. J. E. RAINWATER. 44: 4, 133, April, 1931. With location of additional industries at Cedartown, Georgia, necessity for increased water pressure became urgent. Standpipe of 1½ million gallons capacity was decided upon. It is 80 feet in diameter and 42 feet high; an attractive walkway around the top, with supporting brackets and artistic hand rails, was designed not for architectural effect, but as a rigid stiffening member. Site was selected on ground of high bearing character, so as to minimize cost of concrete foundations.—*Arthur P. Miller.*

The Water Supply of Pittsburgh, Pa. Anon. *The American City*, 44: 5, 89-90, May, 1931. In 1824 Pittsburgh, Pa., made its first move to procure a water supply. In 1826 sites for reservoir and for pumping station were purchased and in 1828 system was ready for service. In recent years extensive improvements have been made on purification and distribution systems, until today inclusive reproduction valuation of undertaking stands at \$65,000,000. Except for small areas supplied by private water companies, entire district is taken care of by public supply which includes 8 pumping stations, slow sand filtration plant, 5 reservoirs, and 12 tanks with storage capacity of 413,000,000 gallons, besides miles of pipe and other accessories. Average daily consump-

tion is about 125,000,000 gallons. Treatment is briefly described. Reduction in typhoid fever in Pittsburg is well known. In 1908 typhoid death rate was as high as 122 per 100,000, while in 1929 it had dropped to 0.6. Water-waste surveys have been very successful, as indicated by fact that in first six months of 1930 leaks totalling over 3,000,000 gallons per day were detected and stopped.—*Arthur P. Miller.*

Valves Inserted in 20-Inch Water Main at Bridge Crossing. J. GIL DAVIS. *The American City*, 44: 5, 102, May, 1931. At Newport, Kentucky, 20-inch cast iron bell-and-spigot water line crosses over bridge subject to heavy traffic. Vibration has caused much trouble from leaky joints and it was decided therefore to put valve in the line at each end of bridge as measure of precaution. Method of inserting valves without interruption to service by means of A. P. Smith valve-inserting machine is described.—*Arthur P. Miller.*

New 20,000,000-Gallon-Daily Pumping Unit Replaces Old Pumping Engine at Cambridge, Mass., Water Works. Anon. *The American City*, 44: 5, 105-106, May, 1931. Need for new pumping engine at Cambridge, Massachusetts, led to study of available types and selection, after much consideration, of horizontal cross-compound crank and flywheel condensing type. Twenty-million-gallon unit was installed in September, 1930. Pump and auxiliary equipment are briefly described. Each bidder had been required to guarantee the duty in million foot-pounds of work to be performed per thousand pounds of dry steam consumed, under penalty for each million foot-pounds by which performance should fall short of guarantee. In case of this unit, performance on trial run exceeded guarantee.—*Arthur P. Miller.*

A New Method of Raising Valve Boxes to Pavement Grades. E. T. CRANCH. *The American City*, 44: 5, 106, May, 1931. New Rochelle, N. Y., Water Company has adopted a system which has proved satisfactory and economical. An aluminum or sheet metal shell is used as adapter, its base fitting into upper half of valve-box casting and its upper end being shaped to hold the regular valve-box cover snugly. When a box is found covered, paving is first cut away, the adapter then inserted and rotated down into position with mortar around it. Quick-setting cement is used, so that boxes are soon ready to receive traffic.—*Arthur P. Miller.*

Linings for Water and Sewer Pipe and Their Effect on Pipe Coefficients. ALEXANDER POTTER. *The American City*, 44: 5, 119-121, May, 1931. Special linings for cast iron pipe to reduce loss of carrying capacity resulting from tuberculation are of economic importance in systems conveying aggressive water, or sewage. In a force main their value lies in preventing constant increase in pumping head. Roughness of interior of pipe is of major importance because of relation of friction coefficient to carrying capacity. For example, HAZEN-WILLIAMS coefficient, C , for badly tuberculated pipe might be 80, whereas for new pipe with a very smooth lining it would be 150. Capacity in latter case is $87\frac{1}{2}$ per cent more than in former, assuming same head loss. Centrifugally applied linings, both cement and bitumastic, and methods of

applying them are described in some detail. Bitumastic enamel lining, centrifugally applied, has smooth and glossy surface, looking very much like black porcelain. Several tests of Talbot-lined pipe, which is so similar in surface appearance to bitumastic-lined that similar coefficients may be expected, gave value for C of 161.2. High points of specification for bitumastic enamel lining included (1) clean castings before coating, (2) selected tar dip, (3) enamel to be centrifugally applied in molten condition to the cold pipe, and (4) outside coating of whitewash. Consistency of enamel must be such as to withstand temperature ranges to which it might be subjected by exposure to sun, or by heating in vicinity of joints when jointing material is poured. In shipping lined pipe, precautions should be taken to protect it from hot cinders.—Arthur P. Miller.

Typhoid Epidemic and "Water Sickness" in a Village. WILLFUHR and BRUNS, H. Veröffentlichungen aus dem Gebiete der Medizinalverwaltung, 1928, 27: 3; Gas- u. Wasserfach, 1929, 72: 782. In 1920, typhoid epidemic broke out in village in Möhne valley, and was traced to infection of the tap water, from which, however, Möhne reservoir was free. In 1927, in same village, appeared "water sickness," a form of gastro-enteritis like that which preceded Hanover typhoid epidemic of 1926. Author discusses literature on subject of this disease and recommends that more attention should be paid to connexion between impurities in drinking water and appearance of enteric diseases.—M. H. Coblenz (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Development of Taste on Treating Water Containing Phenol with Chlorine. DIÉNERT, F., and WANDENBULCKE, F. Rev. d'Hyg. et de Méd. Préventive, 1929, 51: 489. In water containing phenol in concentrations higher than 10^{-10} , chlorine produces an iodoform taste that is attributed to the formation of an oxychlorophenol. Experiments were made on effect of addition of chlorine to water containing phenol in concentrations of 10^{-8} , 10^{-7} , and 10^{-6} , amounts of chlorine added varying from 0.1 to 1.0 mg. per litre. With spring water, iodoform taste increased with chlorine dose to a maximum at 0.6 mg. of chlorine per litre with all three concentrations of phenol. Thereafter it decreased with the lower concentrations of phenol, but not with that of 10^{-6} . Taste diminished more or less rapidly on storage. With river water, taste increased with phenol dose, but also with chlorine dose. It increased on standing to maximum, generally at end of one hour, remained stationary for a time, and then decreased. In darkness results differed but little. Addition of thiosulphate hastened disappearance of taste. When thiosulphate was added before chlorine, taste still appeared. When chlorine was added to phenol-free water, the free chlorine neutralised by thiosulphate, and phenol then introduced, no taste appeared. Most certain method of preventing taste is to destroy phenol with permanganate; 0.58 mg. of permanganate is necessary to destroy 0.1 mg. of phenol. Tastes produced by the three commercial chlorophenols, *ortho*-, *para*-, and trichlorophenol, are not like that of iodoform, and they diminish by degrees. Chlorinated water may dissolve phenol in

new pipes or from tarred cord used at pipe joints and thus develop taste. This is less to be feared if strong doses of chlorine are used, which usually remove all taste.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Filter Plants for Treating Industrial Effluents, Their Application, Construction, and Distribution. Part 2. TESCHNER, G. *Kl. Mitt. Ver. f. Wasser-, Boden- u. Lufthyg.*, 1929, 5: 193. Part 1 of this article appeared *ibid.*, 1928, 4: 256. *Wagner Filter.* Suitable for treating water for industrial use and for removing insoluble substances from industrial effluents. It is in form of cylindrical rotating drum, whose cover is composed of separate segments covered with fine metal cloth. Water enters inside of drum at one end and runs out through sieve-work. Retained matter is carried upwards by slow revolution of drum, and is washed down by syringing into channels discharging at opposite end. Individual segments of cover can be removed and replaced without interrupting flow. Filter can be adapted for use with different kinds of effluents. It is supplied in two sizes, with respective capacities of 10 and 15 cubic meters [2650 and 4000 gallons] per minute. Power required is less than 1 h.p. List is given of works in which this filter is used.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Softening Water. BLAKISTON, R. B. P. 315, 547: *Ill. Off. J. Patents*, 1929, 2120, 4838. Patent concerns a portable water-softening device. Vessel, with loose cover, contains zeolite, and has on one side a channel containing filtering material which can be removed by a rod. Water is either poured into the channel and passes upward through zeolite, or is supplied over the zeolite and leaves through filter channel.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Softening of Magnesium-Containing Water by the Lime-Soda Process. TROTMAN, S. R. *Dyer and Calico Printer*, 61: 192 and 268; *Chem. Zbl.*, 1929, 2: 1446. Discussion of influence of magnesia, neutral salts, applied chemicals, pH, temperature, excess $\text{Ca}(\text{OH})_2$, organic matter, and of separate addition of chemicals. Most suitable quantities of $\text{Ca}(\text{OH})_2$ and Na_2CO_3 are calculated.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Purification of Water by Base Exchange. DIÉNERT, F. *Chim. et Indust.*, 1929, 22: 249. Account is given of history of discovery and of application of natural and artificial zeolites, and of development of methods of manufacture of artificial zeolites and, later, of treatment of natural zeolites. Base-exchange materials in general use in different countries, their classification into porous and non-porous, and their general composition, appearance, and properties are discussed: as also are questions of cost and of measurement of

exchange and regenerative capacities.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Unique Water Purification Plant: Dual Process at Welbeck Colliery. Iron and Coal Trades Rev., 1929, 119: 217. Illustrated description of plant recently erected at Welbeck Colliery. By treatment adopted, scale formation and corrosion are reduced to minimum and concentration of boiler water is controlled to prevent wet steam due to priming. Water is first pre-treated with lime and soda-ash and clarified through pressure filters, after which domestic supply for colliery village is taken off. Boiler feed water is further softened in Bobby "Azed" base-exchange softener which removes remaining hardness without altering alkalinity. Soft water then passes successively through heat-interchanger, hot side of which is fed from continuous blow-down arrangement of tubular boilers, exhaust-steam heater, and live-steam feed-water heater and de-aëerator in which it is boiled for several minutes. Boilers are equipped with Bobby patent continuous safety blow-down. Detailed descriptions of different units of plant are given. Special feature is the driving off of occluded and dissolved gases in the de-aëerator without assistance of vacuum: steam is applied to raise water to 212°F.: water enters above and flows downward meets steam flowing upwards: violent agitation thus set up and boiling temperature liberate all gases, which are carried off through vent pipe. Continuous blow-down arrangement precludes any risk of boiler emptying below low-water level and provides technical control over concentration of boiler water: heat is recovered in heat-interchanger. Plant is designed to provide boiler control at working pressure of 350-400 pounds per square inch, or greater, and is capable of treating 360,000 Imp. gallons daily. Boilers have remained in perfect condition since its introduction.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Modern Methods of Boiler Feed-Water Preparation. HOFER, K.: Glückauf, 1929, 65: 1067. Author gives general survey of recent work on prevention of corrosion, scale-formation, embrittlement, attack by oxygen, and foaming and priming in boilers, dealing with the work of HALL, SPLITTGERBER, PARR, STRAUB and KNODEL. Method of calculating the "soda-number," that is, the amount of alkali necessary for prevention of corrosion, is explained. For prevention of scale-formation at low pressures, soda is recommended; at high pressures, alkaline phosphate. To prevent embrittlement by concentration of caustic soda in seams of riveted boilers, addition of sodium sulphate in definite relation to soda content and to pressure has been used, and same result can also be achieved by alkaline phosphate in very much smaller quantity.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Sanitation and Water Purification. HAWORTH, J. Rep. of the Progress of Applied Chemistry, Soc. Chem. Indust., London, 1928, 13: 588. Author briefly reviews aims and work of different committee and other bodies dealing

with sanitation and water supply and discusses reports issued by the Joint Advisory Committee on Rivers Pollution, the Water Pollution Research Board, the Research Sub-Committee of The Institution of Gas Engineers, the Manchester Rivers Department, and the London Metropolitan Water Board. Survey is then given of papers published dealing with activated sludge process and other methods of sewage disposal, sludge digestion, purification of trade wastes, and water supplies and their treatment. Short summaries are given of published papers and reports.—*M. H. Coblenz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Sheffield England, Water Supply. TERREY, W. J. Roy. San. Inst., 1929, 50: 205. Sheffield has so far obtained all its water within a radius of 15 miles from centre of city and has now appropriated last watershed within easy reach. Drainage area covers 47 square miles. There are 14 storage and 30 service reservoirs. Description is given of position and capacity of storage reservoirs and of joint action of Sheffield, Nottingham, Leicester and Derby, by which joint supply is drawn from Derwent Valley and distributed. Supply pipes from service reservoirs for Sheffield are, on account of physical configuration of the town, laid in three zones, to supply the higher, middle, and lower parts of city. Average daily quantity of water drawn from reservoirs is 35 million Imp. gallons, of which 13½ million gallons is sent down the streams as "compensation water." All water is filtered through sands beds or pressure filters. New plant has been installed for dealing with Derwent supply, including preparing and measuring apparatus for coagulants and lime, pressure filter units, and engine-driven rotary compressed air blowers for cleaning filters. Water is pure and soft, and trouble owing to action of moorland water on lead pipes has been overcome. Total capital cost for provision and distribution of water to 1929 was £7,299,719 and total revenue, £408,340.—*M. H. Coblenz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Tetbury (Glos. England,) Water Supply. Surveyor's Report on Borehole Drilling Operations. HEARSEY G. Summarised in Surveyor, 1929, 76: 311. Boring of a partly concrete, partly unlined, and partly lined and slitted borehole, 496 feet 6 inches in depth, is described. Abundant supply was obtained, but it was unsafe, bacteriologically. Contamination was thought to proceed from two small boreholes made in 1892. These were cleaned out and bleaching liquor pumped down them; pump on new borehole was started and water was kept flowing from the old holes and up the new, thus cleansing the strata round boreholes, until analysis showed that ground was purified. Old boreholes were then filled in with liquid cement grout. This method proved entirely satisfactory. Geological drawings are given.—*M. H. Coblenz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Water Supply of Wellington, N. Z. Report of the City Engineer. Surveyor, 1929, 76: 197. Report by G. HART, which is here summarised, deals

with present position and estimated requirements of City of Wellington and its suburbs. Comprehensive investigation has been carried out of streams, proposed conduit routes, dam and weir sites and reservoirs, stream flows and rainfall data, and requirements of the area. Author concludes that future extensions should provide for not less than 80 Imp. gallons daily per capita. He estimates that if work on development were started before end of 1930, supply should be available for whole area embraced by Water Board by 1934. In dealing with storage capacity, he describes effects of drought of 1917 and estimates that if similar conditions should occur in 1934, present storage capacity would be exhausted in 67 days and city, with normal demand estimated at 9.36 million gallons a day, would be dependent on stream flows totaling 3.75 million gallons a day.—*M. H. Coblenz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Drinking Water for Travellers in the Tropics. SHATTUCK. *Jour. Tropical Med. and Hyg.*, 1928, 31: 229; *Office Intern. d'Hyg. Publique, Bull. Mensuel*, 1921, 21: 1234. The Harvard African Mission, which spent a year in Nigeria and Belgian Congo, found that hypochlorite of lime was too unstable to be satisfactory for water sterilization. Halazone proved entirely satisfactory. This is composed of 4 per cent sulphodichloramino-benzoic acid, 4 per cent sodium carbonate, and 92 per cent sodium chloride, compressed into tablets of from 100 to 105 mg. If at full strength, one tablet per litre of water gives chlorine concentration of one part per million. As coagulant, either potassium or ammonium alum was used, aluminium sulphate being too hygroscopic.—*M. H. Coblenz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Disinfectant Action of "Caporite." PIOTROWSKA, H. *Gaz i Woda*, 1928, 8: 228; *Chim. et Indust.*, 1929, 22: 270. Caporite contains, in addition to calcium hypochlorite, a certain quantity of free chlorine. Comparative disinfecting powers of phenol, caporite, and bleaching powder are 100, 120, and 35; 1.3 parts of caporite are therefore sufficient to disinfect from 1 to 2 million parts of water. Ten samples of water from different sources, with bacterial contents varying between 199 and 12,500 per cc., were treated with caporite. After one hour number of bacteria was reduced, on an average, to 1 per cent.—*M. H. Coblenz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

When Is the City Liable for Damages From Operation of Water Works? LEO T. PARKER. *Water Works Eng.*, 84: 13, 949, July 1, 1931. Court decisions do not hold city responsible for damage due to overflowing drains after an improvement has been made, if water overflowed same property before. Flooded cellars due to breaks in water mains are not retractable to water company unless negligence is proved. Some municipalities have ordinances establishing definite time limit on damage suits. Courts have sustained these ordinances. Another important point of law is that rules adopted by municipi-

pality, or by private water company, are equally as effective with respect to consumers and other citizens, as state or city laws. It is well established that when making excavations, or digging trenches, care must be exercised by responsible party to prevent drainage to adjacent property, in event of heavy rain suddenly flooding surrounding land. It is well established law that cities own the streets and are not responsible for damages to utility properties if due care is taken under construction.—*Lewis V. Carpenter.*

Tastes and Odors in Small Water Supply Removed by Ammonia. J. E. LYLES. *Water Works Eng.*, 84: 14, 1003, July 15, 1931. Tampa, Fla., has plant of 12-m.g.d. capacity. Raw supply varies between being soft and highly colored and being fairly hard and only slightly colored. Acid manufactured at plant is used with alum for pH adjustment. Recarbonation equipment is provided. An unpleasant, medicinal taste and odor in 1928 led to some experimental work for its removal. Aeration proved successful on a small scale, but was not adopted. To maintain residual of from 0.2 to 0.3 p.p.m., 16 pounds per m.g. of chlorine was being required. A rather unique type of ammoniator was introduced, consisting of pressure reducing valve and orifice and manometer to measure loss of head through orifice. Ammonia is added immediately after filtration, just far enough ahead of chlorine to secure intimate mix. Lime is added after chlorination to bring pH to 7.8. Ammonia treatment had three results: (1) elimination of medicinal odor and taste; (2) more effective sterilization, eliminating after-growths in distribution system: residual of 0.4 p.p.m. at plant suffices to eliminate all growths; (3) saving of approximately \$2000 per year in cost of sterilization: before introduction of ammonia, 16 pounds chlorine, costing \$1.40, were required per m.g.; but since then 5.6 pounds chlorine and 1.9 pounds ammonia together costing \$0.94, have sufficed. Table is given showing amounts used and saving in cost obtained.—*Lewis V. Carpenter.*

Methods of Prospect Drilling for City Ground Water Supplies. HOWARD E. SIMPSON. *Water Works Eng.*, 84: 15, 1071, July 29, 1931. Location and number of test holes are important. In glacial sands, any point within radius of 100 feet is satisfactory; while in sedimentary bed rock formations, distance of one-half mile might be unimportant. Possibility of sub-surface pollution should be investigated thoroughly. Esthetic side of location should not be overlooked; in a park, it has real value as a show spot. Author gives a set of 12 specifications for prospect drilling for water.—*Lewis V. Carpenter.*

Filter Washing. ROBERTS HULBERT. *Water Works Eng.*, 84: 14, 1973, July 29, 1931. When water passes upward through a sand filter, volumetric expansion of sand layer takes place and proportion which this increase bears to volume of settled sand is called the sand expansion. Amount of this expansion depends on several basic factors, notably size, specific gravity, and shape of sand grains, and velocity and viscosity of applied wash water. Sand expansion offers a nearly perfect index of intensity of wash because sand is expanded by wash water until equilibrium is just established between the downward gravitational pull on the sand particles and the resultant upward

pressure of the wash water. Water becomes more viscous, less fluid, as its temperature decreases, therefore friction between it and sand becomes greater and scouring effect on sand grains, enhanced. Cold wash water requires less upward velocity to float the sand than warm. Curves are given which show that to obtain equivalent washing results, velocities $1\frac{1}{2}$ times greater must be employed in warm water months than in winter. Assuming constant specific gravity, difference in grain size affects sand expansion. This is because the effective weight of the sand particle is a function of its size which increases as the cube of the diameter, while surface area increases only as the square. Author uses the 30 per cent size as index of size, rather than effective size. Curve is given which shows that where diameter ratios are as 1 to 1.33, wash velocities for 50 per cent sand expansion are as 1 to 1.56. Sand expansion is usually expressed as percentage, based upon settled sand depth, rather than as inches of actual lineal rise. Shape of sand grains must have significant influence upon sand expansion, but it has not been evaluated. Alterations in density of filter medium result in marked changes of behavior in backwashing. Aluminum hydrate and clay are much lighter than sand and the more the sand coats, the more moisture it retains and the lighter it becomes. Tabulations are given of variations in procedure required to produce a 50 per cent sand expansion corresponding to variations in. (1) size of sand; (2) water temperature; and (3) specific gravity of sand. Filter operator can vary wash rate to suit conditions. The sand needs violent scrubbing and proper selection of wash water rate will give this.—*Lewis V. Carpenter.*

Some Diesel Engine Jobs in Service in New England. Anon. *Water Works Eng.*, 84: 15, 1086, July 29, 1931. Marshfield, Mass., uses two 60-h.p. F. M. Diesel engines connected to triplex pump. Engines are equipped with speed regulators which permit speeds from 160 to 257 r.p.m. They have been operated for about two years without trouble, pumping against head of 250 feet with 13-inch vacuum on suction line. Supply is drawn from 58 wells $2\frac{1}{2}$ inches in diameter and ranging from 25 to 40 feet in depth. Duxbury, Mass., had originally two 30-h.p., 4-cycle, single-cylinder, horizontal oil engines, each connected to a vertical triplex pump. New 60 h.p. Diesel engine was installed and, with fuel oil costing 9 cents per gallon, fuel cost now averages \$8.75 per m.g. pumped against head of 100 pounds with 7-inch vacuum on suction. In Spring of 1926, Salem, N. H., installed a 25-h.p. engine belted to centrifugal pump. In 1929 a 40-h.p. Diesel engine connected through a Poole speed increaser, was connected to a 1418-r.p.m. pump delivering 800 g.p.m. against head of 130 feet.—*Lewis V. Carpenter.*

Coordination in the Sanitary Control of Bottled Mineral Waters. W. S. FRISBIE. *Public Health Reports*, 46: 32, 1873, August 7, 1931. Over 400 springs, or wells, in the United States have been commercialized; but only a small proportion are active at present. Nevertheless there is a substantial local and interstate traffic in bottled waters. Regulatory control, from stand-points of sanitary quality and therapeutic claims in labeling of the interstate package, is vested in Food and Drug Administration of U. S. Department of Agriculture. The Administration purchases from dealers, handlers, and

consumers of these products, adequate samples for bacteriological and sanitary chemical analyses. Several hundred are examined annually. About 10 or 15 per cent of the samples are found to be polluted. Additional samples of latter are collected and examined, and formal action leading to confiscation of polluted shipments and prosecution of shipper is instituted under Food and Drug act. Standards employed in determining pollution are essentially same as those used by U. S. Public Health Service in control of water on interstate carriers. Laboratory examination is supplemented, wherever possible, by inspection of sources of supplies. Closer coordination between food and drug Administration and State health officials charged with sanitary control of public water supplies might be beneficial to all concerned. It would be advantageous if the Administration were informed as to measures taken by State departments with reference to sanitary inspection of sources of supplies and conclusions drawn therefrom, reports of laboratory analyses, and recommendations for improvement. In turn, Administration would supply State health departments with any information necessary to the desired coordination.—*R. E. Noble.*

A Nomogram for the Calculation of Dissolved Oxygen. C. T. WRIGHT, and EMERY J. THERIAULT. Supplement No. 95 to Public Health Reports, 1931. Authors present nomographic chart to facilitate calculation of dissolved oxygen by the usual WINKLER method when total bottle contents, between the limits of 235 and 310 cc., are titrated. Description and examples of its use are given.—*R. E. Noble.*

Steam Piston Pumps in Germany. E. IMMERSCHITT. *Water and Water Engineering*, 33: 392, 377-379. More than 40 per cent of water in Germany is raised by piston pumps, owing to their high efficiency and reliability; fluctuating delivery volumes and heads are not detrimental to piston pump operation, but centrifugal pumps must be worked at optimum delivery and head to give high efficiency. New piston pump of Hattersheim (Frankfurt) pumping station, working under very fluctuating conditions, gives results 10 per cent better than the most economical steam turbine pumps. Engine is vertical; steam pressure is 270 pounds per square inch with temperature of 350 C.; and steam consumption in two tests was 8.5 and 8.52 pounds per horse power hour, the lowest ever attained with a pumping set. The three differential pumps have each 19.7- and 15-inch cylinders and 35.4-inch stroke. Speed can be varied between 25 and 60 r.p.m. Each pump has 14 suction valves and 14 delivery valves above them.—*W. G. Carey.*

Modern Water Supply. *Water and Water Engineering*, 33: 392, 383-384. R. G. HETHERINGTON, chief engineering inspector to Ministry of Health, in reviewing water supply in England during last twenty-five years says that most important factor has been constant increase in consumption per head, quite outweighing increase due to growth of population. This period has seen birth and rise of mechanical filtration; need of storage for purification has been realized; and chlorination has ceased to be an emergency, and is a routine, process. There has been no marked change in general design, but new ma-

terials, e.g. reinforced concrete, spun pipes, and centrifugal linings, have been introduced. Closer touch has been established between central and local government and regional water committees have been established.—W. G. Carey.

Bartley (Birmingham, England) Reservoir. Anon. Engineer, 152: 109, July 31, 1931. Escape of water was observed when reservoir was filled. After boreholes were sunk, consultants reported existence of narrow disturbed, or faulted, belt in twenty-foot seam of pervious rock, and recommended that number of boreholes be sunk and cemented, chiefly into disturbed portion of area and on either side of it. There is no indication of any leakage through dam, or other part of reservoir construction.—W. G. Carey.

The Nile Waters. Anon. Engineer, 152: 109, July 31, 1931. Aërial photographic survey of Lake Albert area is being made as part of scheme to provide additional water supply. Estimates state that two-thirds of water flowing into the Nile from lake is wasted in sudd area; one project to avoid this is to cut channel through the sudd, and survey will supply data for preparing plans; scheme involves building dam at Pakwach on the lake to raise water level 25 feet and to enable source of waters to be controlled.—W. G. Carey.

Some New Ideas on Dams. E. GODFREY. Contractors Record, 91, January 23, 1931. From British Waterworks Association Official Circular, 14: 92, 233, April, 1931. Practically every failure of a dam is due to underpressure and neglect to provide for underpressure in the design of masonry, concrete, or earth, dams. Design will never be on sound basis until underpressure is recognized to be as important as water pressure on the up-stream face of dam.—W. G. Carey.

The Effect of Water Treatment upon Ferruginous Encrustations. A. GODFREY. Water and Water Engineering, 33: 387, 121, March 20, 1931. Acidity, dissolved iron, iron bacteria, and dissolved oxygen cause iron oxide deposits. Dissolved iron may be partially removed by aëration and filtration, Upland soft water often has a pH from 5.6 to 6.4 and various forms of iron bacteria, predominating form being influenced by pH value; crenothrix appears in acid waters; leptothrix, gallionella, and spirophylla are fairly general, with optimum growth on the acid side; while cladothrix has been observed in water of pH 7.2. Bare patches, or pinholes, form starting point of incrustations, owing to local concentration cells of dissolved iron. Lime has little action on bacterial growth until pH of 8.0 to 8.5. No benefit is obtained by hardening the water and sodium silicate gives no useful results. Author states that only sure method of stopping growth is to scrape the pipes and recoat them.—W. G. Carey.

Influence of High Temperature and Addition of Salts on the Lime-Carbon Dioxide Equilibrium and the Lime-Rust Protective Layer. J. TILLMANS, P. HIRSCH and W. R. HECKMANN. Gas-und Wasserfach, 74: 1, 1-9, January 3, 1931. Details are given of the determination of the equilibrium in water

between free carbon dioxide and calcium bicarbonate, together with results at 40°, 60°, 80°, and 100°C.; an equilibrium equation is derived and is shown to hold for temperatures higher than normal. Effects of sodium bicarbonate and chloride, of calcium chloride and sulphate, and of magnesium chloride upon the equilibrium are described. Experiments on the formation of a lime-rust protective layer indicate that protective layer is formed above room temperatures when oxygen is present and free carbon dioxide is not in excess of that necessary to keep bicarbonate in solution. Methods of analysis are given, with diagrams, tables of results, and curves.—*W. G. Carey.*

Compensation by Water Works for Withdrawal of Ground Water. HEINE. *Gas- und Wasserfach*, 74: 5, 107-110, January 31, 1931. Law of compensation for damage done by withdrawal of ground water is discussed; e.g., damage to fruit growing by lowering ground water level. A yearly amount is inadmissible and a capital sum is substituted, calculated from ground value and not from proceeds derived from it.—*W. G. Carey.*

Water Purification Plant for Königsberg. G. SATTLER and R. BRÜCHE. *Gas- und Wasserfach*, 74: 4, 73-76: 5, 101-104: 6, 128-130. Prior to 1928, supply, which is from shallow wells and impounding reservoirs, was pre-treated in coarse filters before passing through slow sand filters. Additional plant, using aluminium sulphate as coagulant, has been erected and was designed to utilise existing machinery and to conserve water, supply of which is limited. There are twelve rectangular, open, rapid filter units with air-water washing. After addition of aluminium sulphate and, if necessary, of chlorine and of lime, water settles for 4½ hours in 6 settling tanks, each of 1½ million U. S. gallons capacity. After passing through the rapid filters, water goes to the old slow sand filters, but, if necessary, the two plants may be run in parallel, the more polluted water being dealt with in the rapid filters.—*W. G. Carey.*

Protection of Exposed Water Main from External Corrosion. Water and Water Engineering, 33: 392, 375-377. A mild steel pipe line 3 feet in diameter in Newcastle, Australia, suffers external corrosion when laid on the surface. Experiments in progress so far show that tar and bituminous paints decompose in direct sunlight and that all coatings last better on lower half of pipe. White and aluminium paints cause less heat absorption than black coverings, water temperatures 10°F. higher having been observed with latter. Aluminium paint has high opacity to chemically active light rays, can be laid on tar or bitumen, and with 14 per cent tung oil in vehicle has good lasting qualities; its cost is not high, owing to high spreading and covering capacity.—*W. G. Carey.*

Irrigation Pipes. Anon. *Water and Water Engineering*, 33: 390, 246. Pipes, upper side of which is porous, are sunk in ground at depth of 12 inches; water led into them percolates upwards to roots of plants. This system is successfully used in South Africa.—*W. G. Carey.*

Water Sterilization by Metals. Anon. *Water and Water Engineering*, 33: 390, 245. In paper to Paris Académie des Sciences, possibility was discussed of purifying water from pathogenic germs by passing it through sand metallized with silver. Subsequent treatment included brief retention in reservoir and filtration through rapid sand filters to remove taste, odor, and any residual microbicides derived from metallized filter.—*W. G. Carey.*

Horizontal Filtration of Water. Anon. *Annales d'Hygiène*, February, 1931, 87-98. From *Water and Water Engineering*, 33: 390, 284, June 20, 1931. The horizontal filtration of nature is simulated by DIÉNERT in zinc-lined box 1.4 meters long, 30 cm. wide, and 30 cm. deep. Baffle plate is fixed 30 cm. from upstream end of box and filter is filled with sand from 2 to 4 mm. in diameter, with layer of pebbles at outlet end to retain the sand. Water is fed through siphon tank and, after initial vertical filtration, passes horizontally to outlet. There is no submersion of sand and real horizontal filtration is obtained, which takes 1½ hours.—*W. G. Carey.*

Chemical Purification of Drinking Water. *Water and Water Engineering*, 33: 388, 149, April 20, 1931. Heyden chloramine has been object of research recently in Germany. The compound contains 24.4 per cent chlorine, is harmless, odorless, and soluble in water and has greater disinfecting power than bleaching powder. Tests on highly polluted water containing *B. Coli* showed complete sterilization.—*W. G. Carey.*

Iodine and Goiter. British Waterworks Association Official Circular, 13: 93, 379-380, June, 1931. Investigations undertaken at Rowett Research Institute, Aberdeen, have led to view that there is no correlation between amount of iodine in drinking water and incidence of endemic goiter.—*W. G. Carey.*

Pipe Investigations at Sydney, N. S. W. British Waterworks Association Official Circular, 13: 93, 370-371, June, 1931. For large mains, welded steel pipe lined internally with cement mortar applied centrifugally and with external wrapping of bituminous compound reinforced with jute fabric is standard practice to obtain extended life and freedom from water discoloration. Investigations are being made upon cement asbestos piping and upon provision in steel pipe of preparatory bitumen lining and blue metal nibs to secure adhesion of cement lining.—*W. G. Carey.*

Protection Against Loss by Pipe Fracture. K. HIDDEMANN. *Gas- und Wasserfach*, 74: 2, 28-31, January 10, 1931. Description, with diagrams, of electric cut-off arrangement with long distance control and of hydraulic cut-off valve which operates when flow exceeds a certain amount.—*W. G. Carey.*

Lowering the Level of Mountain Lakes by Centrifugal Pumps. Anon. *Water and Water Engineering*, 33: 390, 271-276, June 20, 1931. Dammed lake, tapped by gallery, can furnish water only down to gallery level. Alternative method is to instal centrifugal pumps capable of pumping from any level. These

pumps may be (1) stationary, drawing water from shaft connected to reservoir through gallery, (2) movable, being mounted on inclined hoist, adjustable to suit water level, or (3) floating, so as to rise and fall automatically with water level. Among advantages of floating type are the small amount of building and the rapidity of installation. A plant in Austria rests on floating cylinders and is connected to land by 16½-foot lengths of rigid piping connected to each other by 13-foot lengths of flexible steel tubing. As level of water sinks, pipe line settles down on slope of bank.—*W. G. Carey.*

Complex Combinations of Iron and Their Removal from Water. B. A. ADAMS. *Water and Water Engineering* 33: 390, 249-250, June 20, 1931. Soluble iron complexes, similar to those produced from ferric or ferrous salt in presence of citric, tartaric, or malic acids, or of their sodium salts, may occur in water and traces of any of these tend to prevent precipitation of iron as ferric hydroxide in alkaline water. Activated carbon was only effective means of removing these iron complexes; lime, even in excess, was not always successful; and, excepting bleaching powder, oxidizing substances were completely ineffective. Manganese permanganate was effective only in case of tartaric acid.—*W. G. Carey.*

Correlation of Certain Soil Characteristics with Pipe-Line Corrosion. I. A. DENISON. *Bureau of Standards Journal of Research*, 7: 4, 631, October, 1931. Corrosion experienced in the operation of a group of pipe lines in Ohio was found to be related to the kinds of soil which occur along a 32-mile section of the lines. Soils of the Brookston series in this area are non-corrosive. Soils of the Nappanee series proved to be corrosive wherever they occurred. The Wauseon soils occurring in slopes or slight ridges were observed to be corrosive. Other sandy and sandy-loam soils not underlain by glacial material apparently have little corrosive action. A satisfactory correlation was found to obtain between the exchangeable hydrogen present in the soils and corrosiveness as indicated by the quantity of pipe replaced in 1,000-foot intervals. The hydrogen ion concentration of soil samples in normal potassium chloride solution is a fairly satisfactory index to the corrosiveness of the soils studied except in the case of slightly buffered sands. Both methods, however, tend to exaggerate the corrosiveness of well-drained sandy soils. An accelerated laboratory test of soil corrosiveness involving the corrosion of a steel disk in contact with moist soil is described. The results obtained paralleled the quantity of pipe replacements fairly closely in the case of heavy soils. The degree of corrosiveness indicated by the test is influenced by the acidity, texture, and probably by the structure of the soils studied. Since only a qualitative study of the factors influencing the test has been made, the test can not at this time be considered a reliable index of soil corrosiveness except in the case of soils similar to those tested. The methods described for identifying corrosive soils which involve determinations of acidity are probably most reliable in the case of related soils which differ from one another chiefly in their contents of exchangeable hydrogen. The data obtained from the tests are probably insufficient to indicate the relative corrosiveness of soils having widely different physical and chemical characteristics.

NEW BOOKS

Hydrogen Ions: Their Determination and Importance in Pure and Industrial Chemistry. BRITTON, H. T. S. Chapman and Hall, Ltd., London, 1929, 532 pp. 25s. net. Objects of this book have been: (1) to discuss electrometric and colorimetric methods of determining concentration of hydrogen ions; (2) to show fundamental importance of hydrogen-ion concentrations in general chemistry, including volumetric and gravimetric analytical procedures; and (3) to indicate rôles of hydrogen-ion concentrations in various industrial processes and how methods of measuring pH have been used for purpose of control. In dealing with electrometric measurement, author describes the theory, and then deals in turn with different electrodes, describing their nature and use. Colorimetric methods, indicator errors, preparation of indicators, and buffer solutions are discussed in detail. Author then proceeds to consider importance of hydrogen-ion concentrations in inorganic chemistry and in various industrial processes. Leather industry and tanning processes, sugar and paper manufacture, brewing, baking, ceramics, textile and dye industries, and other processes are discussed in some detail. A chapter on "Water Purification, Corrosion, and Sewage Disposal" discusses importance of pH in water softening, in boiler feed waters, in alum treatment of water, in prevention of corrosion, and in activated sludge process.—*M. H. Coblenz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Les eaux d'Égypte (The Waters of Egypt). A. AZADIAN. Ministère de l'Intérieur. Dépt. de l'Hyg. Publique. Notes et Rapports des Labs. de l'Hyg. Publique. No. 7, Vol. 1. pp. xxii and 317. Illust. 1930. Cairo: Imprimerie Nationale. From Bulletin of Hygiene, 6: 4, April, 1931. (Back cover)—*Arthur P. Miller.*